Planktonic Foraminiferal Families Hantkeninidae, Orbulinidae, Globorotaliidae and Globotruncanidae

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Introduction

During the past 10 to 20 years there has been an enormous increase in the recognition of the value of the planktonic Foraminifera as stratigraphic index fossils. They form an excellent basis for precise regional and world-wide correlation. Their dispersal is world-wide, affected only by such environmental factors as temperature and salinity. After death their shells sink to the sea floor, regardless of whether the bottom facies is abyssal, neritic, lagoonal, or reefal. Furthermore, the advent and extinction of species and even genera, from the Cretaceous to the Recent, is so spaced that an excellent and exact zonation can be based on their stratigraphic distribution.

At the present time the value of the planktonic Foraminifera for stratigraphic correlation is masked by the incompleteness of our knowledge and especially by the divergent views of different workers on questions of taxonomic grouping. The basis for systematic separation of planktonic Foraminifera has varied greatly from author to author. Features used by one specialist as being of specific value only are used by others for generic and even family separations. The wide limits allowed for a genus in some instances have almost completely masked the true value of the planktonic Foraminifera for stratigraphic correlation. A critical examination of many species of widely varying geographic and stratigraphic occurrence makes it obvious that there are distinctive groups of species, within a "genus" as previously known, that are quite restricted in geologic range. Other species, attributed to different "genera" may have identical ranges and only minor distinctions for separation, and may even intergrade. For these reasons the classification of the planktonic Foraminifera definitely requires revision on the generic level.

Descriptions and illustrations in many publications, especially early ones, are often too generalized, inaccurate or incomplete for a precise species delineation. Lack of care in the collection of samples and failure to recognize reworking has in some instances given exaggerated geologic ranges. In many instances a disregard for the Rules of Nomenclature has caused confusion.

In order to revise the systematics of the planktonic Foraminifera and to determine their exact stratigraphic ranges and the factors important in their geographic distribution, a cooperative study of this group has been undertaken by a number of paleontologists in both hemispheres. The present article is the first of a series resulting from this project, and was undertaken largely as a basis for future publications. All known genera of the families Hantkeninidae, Orbulinidae, Globorotaliidae and Globotruncanidae have been redescribed on the basis of their type species, and the best specimens obtainable of each of the type species have been figured here. In many instances, both the holotype of the type species and additional topotypes or hypotypes have been figured, and for certain genera additional species have also been included. Although we have placed many previously described generic names in synonymy, we have nervetheless figured the type species designated for those nominal genera, so that the record will be complete.

A general discussion of the planktonic Foraminifera is given here with remarks on their ecology, morphology and terminology, evolutionary trends, and geologic distribution. This is followed by the systematic portion of the paper.

In the present revision, a total of 56 generic names are considered, of which 32 genera are recognized as valid, including 5 proposed as new. Many of the previously described genera are emended somewhat, and recognized as valid on a basis distinct from that originally proposed. Some are used in a more restricted sense, thus becoming of greater stratigraphic value. Others are considered somewhat more inclusive than originally proposed, when neither valid structural distinctions nor differing geologic occurrence would uphold a closer separation.

Of the remaining generic names, 23 are here considered synonyms and suppressed. One name is a homonym and had been earlier replaced by a valid name, by the original author. Incidental to the generic studies, 7 new species are also described.

These 32 valid genera are placed in 4 families, with 7 subfamilies, of which 4 subfamilies are new. The

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family placement of many of the genera is also modified. Family and subfamily definitions are given, with authors and dates cited, and with strict adherence to the zoological Rules of Nomenclature in these higher taxonomic categories as well as in generic and specific names.

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This paper is the result of an exceptional amount of cooperation by paleontologists and organizations throughout the world. We have received aid and encouragement in its preparation from many sources, by the receipt of specimens and literature, the loan of types, aid in collecting material, and financial assistance for the preparation of illustrations.

In a study of this sort, it is imperative that the type species be obtained for each genus. Many primary types of these planktonic genera are present in the U. S. National Museum collections, due to the generosity of their authors, who have deposited primary types here. These include the late Dr. J. A. Cushman, the late W. J. Parr of Australia; and Drs. P. J. Bermudez, Jusepín, Venezuela; W. H. Blow, London, England; P. Bronnimann, Havana, Cuba; A. F. M. Mohsenul Haque, Quetta, Pakistan; C. G. Lalicker, McAllen, Texas; M. L. Natland, Rolling Hills, California; H. H. Renz, Caracas, Venezuela; and R. M. Stainforth, Billings, Montana.

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In order to study the original types of Brady, d'Orbigny, Parker and Jones, and others, and to obtain European topotype material, a visit to Europe was imperative. We are therefore grateful to the Smithsonian Institution for making available the Walcott funds to enable Alfred R. Loeblich, Jr., to spend 10 months studying and collecting in Europe, and to the Guggenheim Foundation who similarly financed 10 months of study in museums, re-illustration of types, and field collecting in Europe by Helen Tappan Loeblich. During their stay in Europe, great assistance was given to the Loeblichs by Dr. H. W. Parker, of the British Museum (Natural History), London, who allowed full access to the Brady and other collections there, and through whom they were able to obtain topotype material from the *Challenger* collections for study and illustration. In Paris, through the courtesy of Dr. Jean Roger, the original types of d'Orbigny deposited in the Muséum National d'Histoire Naturelle were examined, studied, and compared with available topotype material.

Aid in the field, in collecting material used in the present study from classic European localities was given by Drs. H. Hiltermann and F. Schmid of the Amt für Bodenforschung, Hannover, Germany, and in England by Dr. Tom Barnard, Mr. Raymond Casey, and Mr. A. G. Davis. Acknowledgement is also made of the cooperation of Trinidad Leaseholds, Ltd., during the time spent by Alfred R. Loeblich, Jr., in collecting in Trinidad, B. W. I.

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Ecology of the Planktonic Foraminifera

Pelagic animals are those which inhabit the free water of the ocean. They must be independent of any support except that of the water, and maintain themselves in the open water without sinking. A wide range of life is represented in the pelagic zone, including not only protozoans and microscopic plant life, but also ctenophores, cephalopods, copepod crustaceans, and fish. Ecologically speaking, the pelagic life may be subdivided into the nekton, which includes the animals that can swim freely and are independent of oceanic currents, and the plankton, which are only passively floating or suspended forms, and whose independent movement is insignificant in comparison with the movement of the ocean currents. Most of the plankton is small or microscopic and all pelagic microscopic animals are plankton (Hesse, Allee, and Schmidt, 1937, p. 233).

Special Characteristics of Planktonic Organisms

"Living matter is heavier than sea water; its specific gravity ranges from 1.02 to 1.06, averaging about 1.04. Special adaptations are consequently required to prevent animals from sinking. This distinguishes pelagic creatures from animals of the benthal and gives them certain features in common; these appear in various groups by convergent evolution". (Hesse, Allee, and Schmidt, 1937, p. 223).

The state of suspension may be brought about either by a reduction in specific gravity or by added resistance offered to the water by the animal.

Reduction in specific gravity: This may be accomplished by economy in use of skeletal material. According to Rhumbler (1911), *Orbulina universa* from surface waters has a thin shell with walls from 1.28μ to 18μ, whereas specimens from the bottom have walls up to 24μ in thickness. The planktonic *Globigerinas* of the surface waters are distinguished by thin-walled shells from the smaller cold-water species, such as *Globigerina pachyderma*, which may live at greater depths. The amount of calcium carbonate in the shells is also reduced in various genera and species by an increase in size of pores, by enlargement of the aperture, or by the development of supplementary apertures.

Specific gravity of planktonic organisms may also be reduced by taking up relatively large amounts of sea water, as is done by jellyfish. The absolute surplus of weight remains the same, but the relative difference is reduced by an increase in the volume of the organism. Invertebrate marine animals may take up water from their surroundings without injury since their body fluids are isotonic with sea water. Storage of lighter materials is an even more effective method of weight reduction used by some planktonic organisms. This would include internal storage of water of less salinity, of fat globules or even air bubbles. These various modifications of the protoplasm represent a possible field for research in the Foraminifera, for as yet no data are available as to possible differences in the composition of the protoplasm in planktonic and benthonic Foraminifera.

Added resistance to sinking: Increased friction with the water and resistance offered by the surface is obtained by increase in size in the horizontal plane of a sinking body. This method is most effective for small animals, such as Protozoans, which have a high value of surface-weight proportion. This may be accomplished by a flattening of the body itself, as in the development of a radial test, with elongate or clavate chambers, or by the development of lateral projections, such as the spines so characteristic of the Orbulinidae.

Emiliani (1954, p. 153) stated:

> The capacity of a certain foraminifer to live in a water of certain density depends obviously, upon its specific weight; this, in turn, depends upon (a) the specific weight of the protoplasm and its inclusions, (b) the specific weight of the test and (c) the ratio of the mass of the protoplasm and inclusions to the mass of the test. If the first two factors are assumed to be roughly constant for all species, the important factor appears to be the third one; i. e., the ratio of the mass of protoplasm and inclusions to the mass of the test. For a given locality, species in which this ratio is the largest will prefer shallower habitats, while species with a smaller ratio will occupy deeper habitats. . . . If the specific weight surpasses a certain limit, which depends upon the density of the water, the foraminifer may not be able to live within a reasonable distance from the surface and may find itself in a zone too deep for efficient nutrition . . . mutations of pelagic species toward a decrease of the ratio mass of protoplasm to mass of test are more probably deadly, as are mutations of benthonic species in the opposite direction.
>
> A foraminiferal species will change its depth habitat during its lifetime if growth processes modify the ratio above mentioned.

Samples of various species were checked by size groups, and only *Orbulina universa* showed an appreciable difference between the size groups. This is (p. 154) "explained by the fact that in this species, while the mass of protoplasm increased proportionally to the cube of the diameter of the test, the mass of the test increases proportionally to only the square of the diameter, the thickness of the wall remaining approximately constant. Therefore the animal grows progressively lighter and progressively migrates toward the surface".

Some theoretical assumptions could be made on this basis. It could be stated that there is a mechanical sifting, that is, a movement of the animals to the depths at which they can maintain themselves. It has been demonstrated that there is such a vertical sorting according to size in the radiolarians, with smaller species in the warmer surface waters, larger ones below. In part the reverse is true of the Foraminifera, due to the difference in development of the organism, for the larger the specimen the greater the mass ratio of protoplasm to test.

It will be noted that the species restricted to the surface waters are those in which the chambers increase rapidly in size as added, and which have consistently thin shells, large primary apertures and, in the case of *Globigerinoides*, numerous secondary openings as well. This shows a distinct correlation between the characters of these species and the adaptation necessary to maintain them in the surface waters they prefer. It would suggest that fossil species with similar appearance, probably inhabited similar levels in the ocean. The converse is true of *Orbulina* which apparently can live equally well in the higher layers which its increased size, and therefore decreased specific gravity, causes it to occupy in its later growth. Emiliani stated that the shell wall of the specimens he examined remained constant in thickness throughout development. However, in many samples one can find specimens of *Orbulina* with many concentric layers developed, suggesting that some specimens of this species had increased the specific gravity by an addition of shell material and thus regained the lower environmental zone. Rhumblers' comments cited above on the relative thickness of wall of surface specimens of *Orbulina universa* and those from the bottom tend to bear out this supposition.

In this connection, it may be noted that "weight-increasing" additions are not uncommon in the planktonic Foraminifera, a condition which would seem anomalous were it not for the fact that in nearly all instances they only occur in the later stages of development, after the increase in size of the test would otherwise have decreased the specific gravity and caused an involuntary upward migration of planktonic species adapted to greater depths. These "weight-increasing" additions include the development of flanges and thick walls, as in *Sphaeroidinella dehiscens*, a species Stubbings (1939, p. 174) stated to occur most often in samples from deeper water. He suggested this occurrence might be due to the survival of their massive tests as compared with those of more delicate species. It may equally well be due to the environmental choice of the species, and the development of the heavier test be related to the depth at which the organism lived, not an accidental character which merely allowed its preservation in the sediments.

Other examples of weight increasing additions may be the thickened walls of later chambers, found in *Pulleniatina obliqueloculata*, and the marked decrease in the size of the wall pores with increase in the size of the test, also seen in *Sphaeroidinella*. The accessory shell structures or bullae, developed by the entire subfamily Catapsydracinae, may be only apertural protection, but they also would increase the shell weight. This would maintain a constant specific gravity in the specimen with increase in size; interestingly, these accessory features are not found in small or juvenile specimens.

Distribution of Planktonic Foraminifera

The free suspension of pelagic animals favors their wide distribution. In fact it has been stated (Chun, 1892, p. 120) that up to the present time no pelagic forms have been discovered in either the Atlantic or Pacific ocean which are not represented by parallel forms in the other.

Variations in environmental conditions are less frequent and less abrupt in the open sea than in the shore waters. Nevertheless conditions are not uniform and pelagic life is accordingly not completely uniformly distributed. These influencing factors are less complex than in littoral areas where depth, type of bottom, presence of fresh water, and high amounts of suspended sediments change rapidly with consequent influence on the fauna. In the open ocean the most important factors are food supply, temperature, depth, light, salinity, and quantity of suspended sediments. The order of their importance is not certain.

Food supply: The food supply of pelagic animals consists of the plankton itself, the basic supply being the plant portion of the plankton, or the single-celled algae and diatoms. As the Foraminifera are dependent upon the phytoplankton as a food source, which they capture by means of their radiating psuedopodia, they are most abundant where this food supply is at least periodically rich. In counts made in the Bay of Kiel, the planktonic plant cells outnumbered the protozoans by a ratio of 7 to 1 (text-fig. 1). The richest domain of the plankton is the upper 100 meters of the sea water, inasmuch as the plant element in it is dependent on light, and the impoverishment of the plankton begins below this level.

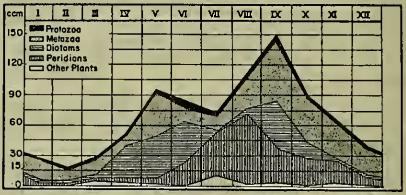


Figure 1.—Curves of volume of various groups of organisms in the total plankton at Laboe, in the Bay of Kiel, during the year. (From Hesse, Allee and Schmidt, 1937, after Lohmann).

Aggregations of plankton also appear in certain areas, especially meeting-places of currents rich in plankton. So-called "animal-streams" may appear in both open sea and near coasts, sometimes with considerable regularity. They form a veritable plankton soup and give a smooth oily appearance to the surface of the water. They may be dependent on wind and current; for example, they appear twice a day in the harbor of Messina (Haeckel, 1890, p. 85). Aggassiz (1892, p. 31) reported these "winrows" of plankton, stating, "The most extraordinary winrows I have met were off the Tortugas, about 150 miles to the northward, where the surface of the Gulf of Mexico for a whole day's steaming swarmed with *Globigerinae*. It was a dead calm." He considered them to occur along the track of the oceanic currents.

The composition of the plankton varies with time as well as locality. For example the protozoans fluctuate from a low ebb in winter to a high in late summer in the Bay of Kiel, reflecting a similar seasonal fluctuation in the numbers of diatoms and other phytoplankton.

Temperature: The geographic distribution of the animal communities of the oceanic pelagial is determined primarily by temperature. There is a subdivision into oceanic communities typical of warm water and those typical of cold water, roughly corresponding to the tropical and subtropical areas on one hand and the cooler waters on the other. These can be further subdivided. Marine animals appear to recognize an equatorial belt of water with a temperature above 25° C. as distinct from cooler tropical waters lying on either side with temperatures from 20°–25° C. Similarly, there are different communities in the cold-water polar areas with temperatures below 10° C. and those of the less cold waters with temperatures between 10° and 15° C. The boundaries are not sharply defined, and they may shift with the seasons, but in general a distinction can be made.

A pelagic community in tropical seas may have 20 species of Foraminifera, whereas one in polar water will have only a few. However, species found in polar faunas may be exceedingly rich in number. The abundance of diatoms in polar seas is an ample supply of food in summer months. In fact, in actual numbers of organisms per liter of water it has been shown that cold water contains about three and a half times as abundant a fauna as the water warmer than 20° C. But this abundance is limited to the summer months, and there is a relative scarcity of life in winter, when the absence of sunlight causes the plant life to remain dormant; so that the total annual production may not be greater than that of tropical seas.

There is a great similarity in the faunas of the Arctic and Antarctic seas. This may partially be due to a connected distribution through the deeper and therefore colder waters between. For example, of 14 Antarctic Foraminifera, 12 also occur in the Arctic, they are partly generally distributed forms, but partly are found normally at great depths and only in the polar regions do they ascend to within 30–70 meters of the surface. (Fauré-Fremiet, 1913, p. 268.)

There are other cases where the identity of the polar forms has been referred to the convergent evolution of species. The thick shelled *Globigerina pachyderma* is found in both polar seas and was considered by Heron-Allen and Earland (1922, p. 190) to be a local subspecies of *G. dutertrei*, a species, found in the intermediate areas, which develops into *pachyderma* under the influence of low temperature.

Wiseman and Ovey (1950, p. 65) consider living planktonic species of Foraminifera to be useful as temperature indicators. They listed the species typical of the various zones as follows: Arctic and Antarctic species: *Globigerina dutertrei* d'Orbigny and *Globigerina pachyderma* (Ehrenberg). Temperate species: *Globigerina bulloides* d'Orbigny, *G. inflata* d'Orbigny, *Globorotalia crassula* Cushman and Stewart, *G. canariensis* (d'Orbigny), *G. truncatulinoides* (d'Orbigny), and *G. hirsuta* (d'Orbigny). Warm and tropical forms: *Orbulina universa* d'Orbigny, *Globigerina dubia* Egger, *Globigerinella aequilateralis* (Brady), *Globigerinoides rubra* (d'Orbigny), *G. sacculifera* (Brady), *G. conglobata* (Brady), *Globorotalia menardii* (d'Orbigny), *G. tumida* (Brady), *G. scitula* (Brady), *Sphaeroidinella dehiscens* (Parker and Jones), and *Pulleniatina obliquiloculata* (Parker and Jones).

Phleger, Parker, and Pierson (1953, p. 17) give the distribution of species in the Atlantic as follows: Species characteristically abundant in low latitudes (less than lat. 20° N.) are *Globorotalia menardii* (d'Orbigny), *G. tumida* (Brady) and *Pulleniatina obliquiloculata* (Parker and Jones). They also occur in lesser numbers in middle latitudes. Abundant in low latitudes, but in lesser abundance in all other localities as well are *Globigerina eggeri* Rhumbler and *Globigerinoides sacculifera* (Brady). Only in high and middle latitudes is *Globigerina pachyderma* (Ehrenberg). Abundant in middle latitudes and rarer in low latitudes are *Globigerina bulloides* d'Orbigny, *G. inflata* d'Orbigny, *Globorotalia hirsuta* (d'Orbigny), *G. scitula* (Brady), and *G. truncatulinoides* (d'Orbigny). Uniformly distributed in uniform abundance over the entire area were *Globigerinella aequilateralis* (Brady), *Globigerinita glutinata* (Egger), *Globigerinoides conglobata* (Brady), *G. rubra* (d'Orbigny), and *Orbulina universa* d'Orbigny.

However, Phleger (1954, p. 8) did not believe that surface temperature was the most important ecological factor in this distribution. He considered that the different faunas were due to different "ecologic water masses," with some mixing of faunas at the boundaries of these water masses. The Gulf Stream was cited as an example of a water mass transporting low-latitude species such as *Globorotalia menardii* (d'Orbigny) into middle latitudes, i. e., the southern Gulf of Maine. These "water masses" had been earlier discussed by Sverdrup, Johnson, and Fleming (1942) and by Thomsen (1935).

Oceanic currents may of course carry the plankton through varying temperature zones. For example, the closed currents of the South Atlantic carry water from the equator to the 48th parallel of south latitude. The plankton in such a current requires several months and even years to return to its origin, about one and one-fourth years in the North Atlantic current, and two and a fourth years in the South Atlantic. Among short-lived plankton, many generations are included in this period. A different condition results in the noncirculating currents, which may carry warm water into a cold region, as does the Gulf Stream, or cold water into warm, like the Labrador current. Here the plankton may be carried from a favorable environment to an unfavorable one in which they may suffer or die. Murray (1897, p. 23) showed that the deposits of pelagic Foraminifera on the sea bottom were greatest where currents of different temperature met. Possibly the water-masses cited by Phleger are themselves an influence because of differing temperatures.

Studies of planktonic Foraminifera in deep sea cores have been made by many workers in recent years. Faunas from sediments below the surface have been recognized as containing species typical of modern faunas of higher latitudes than that of the core being studied. These are generally considered to represent temporarily colder water during the various Pleistocene stages. These studies have been made by Cushman and Henbest (1940); Stubbings (1939); Phleger (1939, 1942, 1947, 1948), and Ericson, Ewing, and Heezen (1952) in various areas of the Atlantic, Pacific, Caribbean, Gulf of Mexico, Arabian Sea, and Tyrrhenian Sea. However, as noted by Phleger (1954, p. 16) this alternation of faunas in a core may not be entirely due to widespread climatic changes influencing surface water temperature variations. Smaller changes in boundaries of water-masses could cause similar fluctuations. Phleger stated: "The position of the Gulf Stream varies considerably, and . . . there are eddies, counter-currents and numerous bodies of water which have been detached from the main water-mass. Certain sequences of cold- and warm-water planktonic Foraminifera collected from this region may be suspected of reflecting such water movements."

For this reason, it would be necessary to show a similar sequence of fluctuation over an area sufficiently broad as to avoid control by minor current changes, in order to correlate these faunal changes with world-wide climatic changes.

The actual cause of these faunal fluctuations is still undetermined. As stated by Ovey (1950, p. 214), it is certain that there are oscillations in the equatorial Atlantic, and that "short-term fluctuations of temperature are unlikely to be traceable in deep-sea cores because sedimentation is slow and there is also the probability that the lag between temperature and faunal change is considerable."

Studies of ocean temperatures during the Tertiary by Emiliani and Edwards (1953, p. 889) by means of oxygen isotopes, showed "that greater mixing of the oceanic waters occurred in non-glacial times . . ." and "adds weight to the point repeatedly stressed by geologists that the climate of the earth was much more uniform in non-glacial times."

This would suggest that perhaps planktonic Foraminifera would be even more cosmopolitan in Cretaceous and Tertiary times than in the Recent seas, and as a result would be of even greater time value, where temperature control would be minimized.

Depth and ecologic stratification: Only a few studies of the distribution of living planktonic Foraminifera have been made on the basis of plankton tows. Early work established that there are approximately 20 or 30 living planktonic species, based on their presence in plankton tows. The largest populations are in the upper layers of water. Schott (1935) obtained several hundred specimens per tow from the upper 100 meters, and considerably less from greater depths. Phleger (1951) found an average population of 5 to 6 per cubic meter of water in the upper 50 meters in the northwestern Gulf of Mexico. However, some stations showed up to 73 living specimens per cubic meter.

Living specimens of planktonic species also were found in sediment samples, and were either bottom-dwelling or living in the 15 to 20 centimeters of water directly above the bottom. According to Phleger (1954, p. 3), "These data certainly suggest that while planktonic Foraminifera appear to be most abundant in the upper water layers they do live throughout the water column all the way to the bottom." Many plankton tows also contain empty tests of Foraminifera which did not sink to the bottom immediately upon death or reproduction of the animal.

Phleger summarized his findings by stating (1954, p. 3): "The fauna in a sediment may represent environmental conditions which existed throughout the entire water column from the surface to the bottom. There may be several populations living in different depth environments, or the same population may be variously affected by environments at various depths. . . .

"Planktonic Foraminifera do not sink immediately, depending upon water turbulence conditions, and may be deposited at some distance from where they actually lived. The distance of such transport cannot be established at the present time and must be variable."

Studies of pelagic Foraminifera on the basis of oxygen isotope ratios by Emiliani (1954, p. 149) showed that different species from the same sample registered different temperatures for their development. They were, therefore, considered to occupy different habitats with respect to temperature and water density and therefore also with respect to depth. "The same species may vary considerably in its depth habitat in order to adjust itself to the proper temperature and water density." Correlating the temperatures at which these species lived with the variation in temperature with depth showed a well-defined stratification. He stated (p. 152) that, "The species *Globigerinoides conglobata, rubra* and *sacculifera* appear to occupy the shallower habitats, followed by *Globigerina dubia, Pulleniatina obliquiloculata* and *Globorotalia menardii*, while *Globorotalia tumida* and *truncatulinoides* occupy the deeper habitats. . . . The stratification with respect to temperature is, therefore, reproduced also with respect to depth; however, as already well known, the different species appear to be much less dependent upon pressure than upon temperature." Further studies showed that species appear to be adapted to waters of the same densities in the different areas, even if this involves considerable differences in pressure. None of the pelagic specimens examined by Emiliani was found to live at a depth greater than about 220 meters.

Studies of specimens of different sizes of various species by Emiliani showed that the majority maintained the same depth habitat during at least most of their lives. The sole exception was *Orbulina universa* which showed the larger specimens to live at progressively shallower depths. This species was therefore considered to change its depth habitat during its development.

The depths at which the planktonic Foraminifera live and the modifications making this depth selection possible were discussed more fully, above, in the section on special characteristics of the planktonic Foraminifera. However, in determining climates, etc., on the basis of planktonic assemblages, the effect of this stratification of habitats should not be overlooked, as colder water forms may well inhabit deeper layers of the pelagial, whereas the surface layer may contain species typical of warmer latitudes, and thus cause an apparent mixing of faunas.

Light: The primary effect of light on the planktonic assemblage would be that on the phytoplankton, to which light is necessary for development. It would have a secondary effect on the Foraminifera, as a result of its effect on their source of food. There is also a possibility of a direct effect of quantity of light on the Foraminifera. This has been demonstrated by Myers (1943, p. 453) on benthonic species, and was suggested as a possibility in the distribution of some planktonic species by Wiseman and Ovey (1950, p. 63). Their sample 8 from the south Atlantic contained a fauna typical of warmer water than did that of sample 2 from the north Atlantic, although the actual water temperature of sample 8 was lower than that of sample 2. "From the positions of these two samples (number 2 is farther from the equator than is number 8) there is a much closer relationship with latitude than with temperature, which suggests the possibility that the distribution of the northern and southern cold species *Globigerina pachyderma* and *G. dutertrei* are at least partially governed by the low illumination in these latitudes . . ." Thus the amount of light may also be a factor in the distribution of species.

Salinity and suspended sediments: According to Ovey (1948, p. 6), for the existence of pelagic Foraminifera deep water is not necessary, but "it appears only to be necessary to have water free from land-derived pollution by river sediments. Globigerinidae are often found in the Mediterranean, for example, in association with relatively shallow water benthic forms, but wherever found the water above has been clear."

This was substantiated by F. Parker (1954, p. 478) in work on sediments of the Gulf of Mexico. She found planktonic specimens to be much rarer in the region of the Mississippi River delta than elsewhere. They do not occur at all in sediments as shoal as in the rest of the area, and she stated, "Their absence in the delta region is probably due to the outflow of the Mississippi River which causes water to flow out over the surface for long distances." She considered (p. 472) that the salinity was not affected much thereby at the shoalest stations, and probably was not a controlling factor for the faunal changes at either side of the delta region. Quite possibly the large amount of sediment in the water in this area of delta formation is the factor controlling the planktonic population.

Similar evidence of a control by suspended sediments is found in fossil material. Although in general the Cretaceous has an abundant planktonic fauna, there are sediments which wholly lack them. An example is the Cretaceous sequence of northern Alaska which contains a fairly large total fauna of benthonic species (approximately 200 species). Planktonic species are absent, however, throughout the entire section ranging from Neocomian through Senonian, except for one thin horizon of Turonian age which contains two or three planktonic species. Tappan (1951, p. 4) stated: "The Alaskan Cretaceous is thus equivalent in age to a portion of the very fossiliferous Cretaceous sediments of the Gulf Coast, but the faunas have little in common other than age. The Gulf Coast fauna is extremely varied with many pelagic forms and a great abundance of calcareous and specialized types, but the Cretaceous of Alaska contains a dominantly arenaceous fauna and has almost no specialized forms." This difference was explained as environmental, as "the Alaskan section contains sands and clays but no limestones, and the clastic sediments are neither clean nor well-sorted, thus suggesting rapid sedimentation and muddy waters." This "graywacke" type of sediment is always very poor in pelagic species, although they may occur in contemporaneous sediments of differing lithologic type.

Morphology and Terminology

In order to avoid repetition, the morphology of the various planktonic genera is more fully discussed in the section on systematics. However, a general discussion is given here, with definitions of the terminology used.

In the past there has been little agreement in the descriptive terminology used in defining the genera of Foraminifera. Brotzen (1942, p. 11) first used a more exact terminology in defining apertures and their position. He defined septal apertures and lateral apertures. The former could be interiomarginal, exteriomarginal, or areal in position, or there could be composite apertures with one in each of two or more positions.

The lateral apertures could be either lateral, lateromarginal, or sutural, according to Brotzen. This was a considerable advance over the earlier statements such as "at the base of the final chamber," but it did not take into consideration the origin of the apertures and their relative importance. Furthermore there are various types of openings in the planktonic Foraminifera which do not fit well into Brotzen's classification.

The types of coiling have also been variously termed. That of *Globorotalia* for example has been termed trochoid by Cushman, rotaloid by Galloway, turbospiral by Brotzen and trochospiral by Glaessner.

The two sides of the test in these asymmetrical forms have also been variously named. Cushman (1948, p. 16) referred to them as dorsal and ventral, the dorsal side being that on which the chambers of all the whorls are visible. Galloway defined ventral as "pertaining to the inferior side, particularly the apertural side in coiled forms; opposite the dorsal side." Dorsal was stated (1933, p. 464) to be "pertaining to the back; opposite to the ventral side." But in some genera of planktonic Foraminifera the primary "ventral" aperture is closed; there are apertures only on the "dorsal" side, and none on the "ventral."

Glaessner (1948, p. 69) defined the dorsal side in high-spired forms as that with the apical surface of the spire, and the base he considered to be the ventral side. He added that in low-spired forms "the evolute side is usually referred to as dorsal and the involute side as ventral."

However, some benthonic genera are attached by the side showing all the whorls, which in life was therefore "ventral" or inferior, and the aperture may also appear on this evolutely spiral side. Thus in these genera the same side might be termed either dorsal or ventral, depending on whether the writer believes the position of the aperture, the position of the test in life, or the visibility of the early whorls to be the most important basis for defining dorsal and ventral. Brotzen (1942, p. 7) therefore, discarded the use of dorsal and ventral and instead used the terms spiral side and umbilical side.

Thus the terminology used by various authors in discussing the morphology is not always uniform, and in some cases the terms used are not sufficiently explicit. A lack of concise and explicit terminology requires lengthy and repetitious explanations with every description.

For these reasons certain terms previously used are here adapted, others are used in a more restricted sense, and some new terms are defined for structures which previously have required the repetitious use of long descriptive phrases for lack of a single concise and explicit term. As only planktonic Foraminifera are here discussed only the terminology used for these genera is given. Examples representative of each term are given, as well as appropriate sketches.

Shape and Form of Test

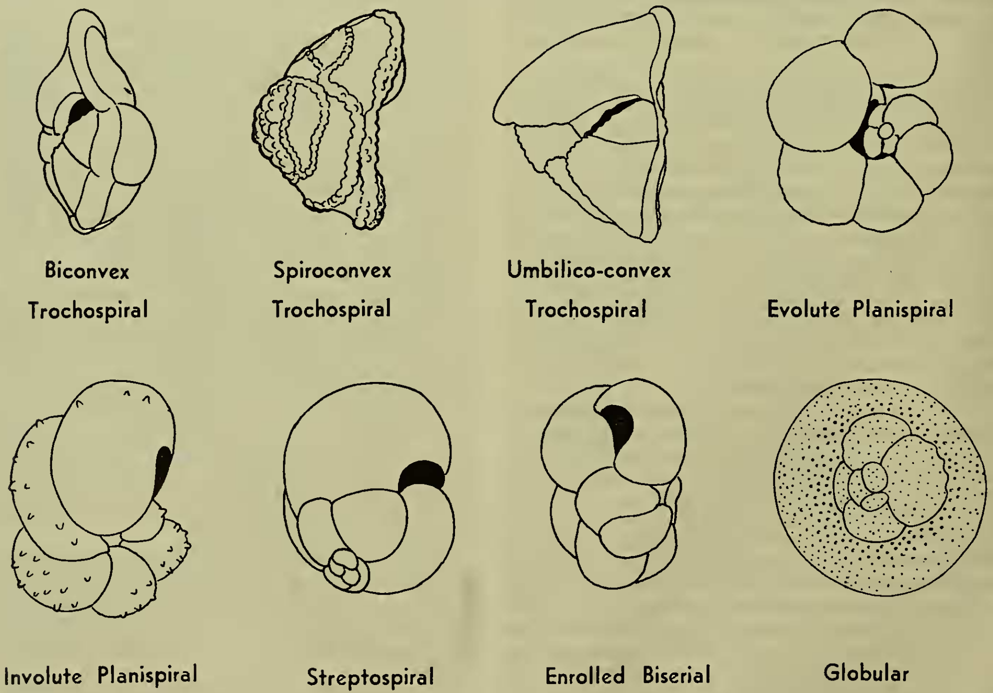
Umbilicate

Those tests with an open or closed umbilicus (the point on the axis of coiling where the septa of the final whorl join in an enrolled foraminifer) on one or both sides of the test (text-fig. 2).

Planispiral biumbilicate: Tests symmetrically coiled, both sides umbilicate, e. g., *Hantkenina.* (This does not include low trochospiral forms although the term has been so used in the past.)

- Evolute. All whorls partially or wholly visible on both sides, but equal on the two sides, e. g., *Hastigerina aequilateralis* (Brady).
- Involute. Only the final whorl is visible on each side, e. g., *Hastigerina murrayi* Thomson.

Trochospiral: Asymmetrical tests with all chambers visible on one side (here termed spiral side, following Brotzen) and only those of the last formed whorl visible around the umbilicus on the opposite (umbilical) side.



Biconvex Trochospiral

Spiroconvex Trochospiral

Umbilico-convex Trochospiral

Evolute Planispiral

Involute Planispiral

Streptospiral

Enrolled Biserial

Globular

Figure 2.—Test shapes in planktonic Foraminifera.

Biconvex. Both spiral and umbilical sides convex, or more or less inflated, e. g., *Globorotalia tumida* (Brady).

Spiroconvex. Spiral side convex, umbilical side flattened to concave, e. g., *Globotruncana contusa* (Cushman).

Umbilico-convex. Umbilical side convex, spiral side flattened to concave, e. g., *Globorotalia truncatulinoides* (d'Orbigny).

Enrolled biserial: This is a modification of the planispiral development in which biserially alternating chambers are enrolled. Characteristic of the nonplanktonic family Cassidulinidae, this type of coiling is also found in *Cassigerinella*, a genus of the family Hantkeninidae.

Nonumbilicate

Lacking an umbilicus (text-fig. 2).

Streptospiral: In the planktonic Foraminifera this may be a later modification of the trochospiral coiling, in which the plane of coiling continually changes, as in the coiling of a ball of string. As the plane of coiling changes, the axis of coiling changes, hence no umbilicus is formed at the terminus of the axis of coiling, e. g., *Pulleniatina*.

Globular: A globular test may be formed, by a completely enveloping final chamber as in *Orbulina;* or by the development of a many chambered test, with rapid increase in chamber size and commonly considerably embracing later chambers as in *Globigerinatheka* and *Globigerinatella*.

Structures of Test

Primary Chambers

The chambers whose pattern of development determine the test shape and form (text-fig. 3).

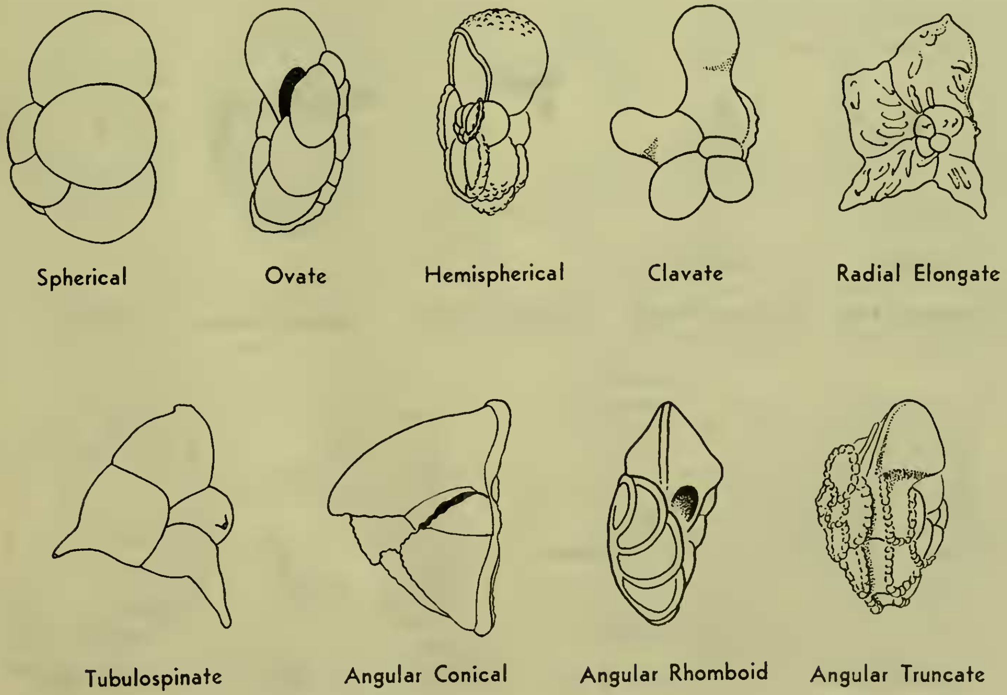
Angular conical: Inflated chambers with angular margins and a conical form as in *Globorotalia truncatulinoides* (d'Orbigny).

Angular rhomboid: Chambers with rhombic section and sharply angled as in *Rotalipora brotzeni* (Sigal).

Angular truncate: Chambers inflated but with truncate margins, angular and commonly keeled, e. g., *Globotruncana arca* (Cushman).

Ovate: Chambers moderately inflated and ovate in section, e. g., *Rotalipora roberti* (Gandolfi).

Hemispherical: Chambers inflated at one side, flattened on the opposite side, and thus hemispherical as in *Globotruncana helvetica* Bolli.



Spherical Ovate Hemispherical Clavate Radial Elongate

Tubulospinate Angular Conical Angular Rhomboid Angular Truncate

Figure 3.—Chamber shapes in planktonic Foraminifera.

Spherical: Individual chambers forming spheres as in *Globigerina bulloides* d'Orbigny.

Clavate: Chambers elongated and may be inflated terminally, having a club-shaped appearance as in *Clavigerinella akersi* Bolli, Loeblich, and Tappan.

Tubulospinate: Chambers produced radially into long hollow extensions, or tubulospines, as in *Schackoina.*

Radial elongate: Chambers produced radially as in *Rugoglobigerina hantkeninoides* Bronnimann.

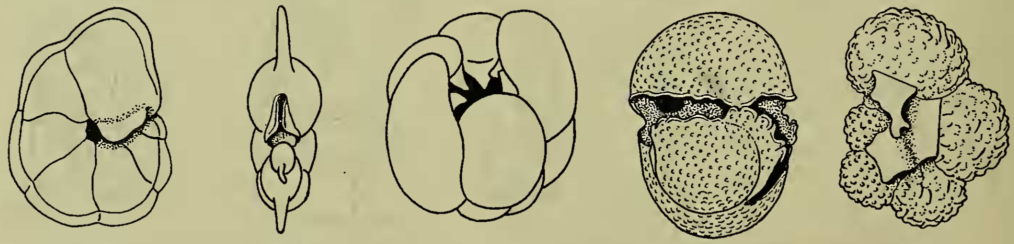
Accessory Structures

These include the structures previously known variously as secondary chambers, chamberlets, umbilical plates, etc., but which are not true chambers as they do not follow the normal chamber arrangement. They are commonly related directly to the aperture and thus may be considered as apertural modifications (text-fig. 4).

A prominent feature of these accessory structures is that they become progressively more prominent with growth of the test and some are developed only in the adult, so that dissection of the tests fails to show any trace of such features as the bullae of the Catapsydracinae. This has been noted before, as F. Parker (1954, p. 477), in discussing a species found in the Gulf of Mexico, stated, "*Globigerina* sp. has a thin supplementary chamber extending from the dorsal side between the last-formed chamber and the first one in the last-formed whorl, to varying degrees over the umbilicus. There are supplementary apertures along the sides of this chamber which in many respects is similar to the supplementary chambers of *Globigerinita.* This chamber is apparently resorbed or destroyed when new regular chambers are added since there is no trace of a previous one."

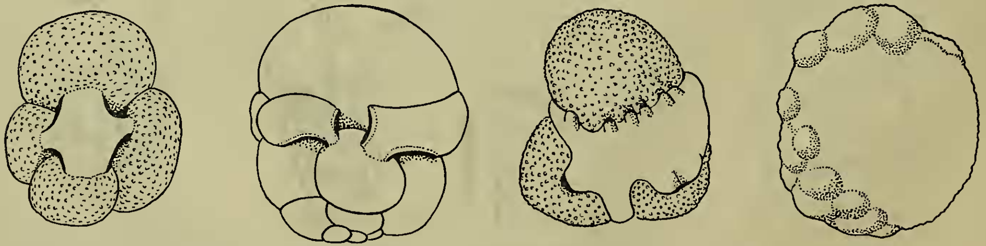
It is probable that these additional structures serve to protect and reduce the size of primary or secondary apertures. They may also be a weight-increasing development necessary in the adult test to maintain the specific gravity of the animal after the increase to adult test size. The structures thus aid the animal in maintaining that depth level in the water where the temperature and water density afforded optimum conditions for the species. Thus, the absence of bullae in younger stages is not surprising. Its presence solely in the adult nevertheless does not lessen its taxonomic value, as many other important characters are developed only in the adult stages of Foraminifera.

Simple apertural lip: This is the simplest form of apertural modification or cover and may be narrow



Simple Lateral

Apertural Lip Apertural Flanges Umbilical Teeth Chamber Flanges Tegilla



Umbilical Bulla Sutural Bulla Umbilical-sutural Bulla Areal Bulla

Figure 4.—Apertural modifications in planktonic Foraminifera.

and elongate, short and spatulate, or of various other shapes, e. g., *Globorotalia*.

LATERAL APERTURAL FLANGES: Similar to the apertural lip of trochospiral forms, but found on both sides of the commonly elevated peripheral aperture in *Hantkenina*, *Clavigerinella*, and related genera.

UMBILICAL TEETH: A triangular modification of the apertural lip, those of successive chambers in forms with an umbilical aperture giving a characteristic serrate border to the umbilicus as in *Globoquadrina*.

CHAMBER FLANGES: Broad folds developed along the basal margins of chambers which tend to obscure the sutures and thereby to cover the sutural and umbilical apertures as in *Sphaeroidinella*.

TEGILLA (singular, tegillum; derivation: Latin diminutive of *tegulum*, roof, cover): This new term is proposed for the umbilical coverings of the Globotruncanidae (*Globotruncana*, *Rugoglobigerina*) which are extensions from the chambers, similar to a highly developed apertural lip, but which extend across the umbilicus, completely cover the primary aperture, and attach at their farther margin or at the tegilla of earlier chambers. Generally delicate and with thinner walls than the true chambers they may be broken out of the umbilical area and are comonly found only as ragged fragments. With great care in preparation of well-preserved material they may also be found in all species of these genera. They may have smaller openings along their margins, or be pierced centrally, these openings communicating beneath the tegilla with the primary umbilical apertures and the umbilical area.

BULLA (plural, bullae; derivation: Latin, blister): This term is here defined to include the accessory structures found in many planktonic Forminifera of the family Orbulinidae, which in general are not closely related to the primary chambers, but are instead related only to the aperture. They may partially or completely cover the primary or secondary apertures, and may have one or more accessory apertures at their margins.

  Umbilical bulla. A bulla covering the umbilicus and the apertures leading into it, as in *Catapsydrax*.

  Sutural bullae. Bullae covering the secondary sutural apertures and only sutural in position, as in *Globigerinatheka*.

  Umbilical-sutural bulla. A bulla covering both the umbilicus and the apertures leading into it and extending along the sutures as well, as in *Globigerinita*.

  Areal bullae. Bullae covering the multiple areal apertures as in *Globigerinatella*.

Apertural Openings in Test

These include the relatively large openings commonly termed apertures, which in general are characteristic for each genus, both in position and shape. The fine pores in the wall for the extrusion of pseudopodia are not considered here (text-fig. 5).

Primary Aperture

This is the main aperture opening from the final chamber of the test. In the families under consideration here, all primary apertures are interiomarginal, that is "at the base of the final chamber," but may vary in position as follows:

UMBILICAL: Opening from the final chamber directly into the umbilicus, on the umbilical side of trochospiral forms. Those of earlier chambers may also remain open, as in *Globigerina*.

EXTRAUMBILICAL-UMBILICAL: Extending from the umbilicus along the forward margin of the final chamber toward the periphery, and thus reaching a point outside the umbilicus, or extraumbilical as in *Globorotalia*.

EQUATORIAL: This is characteristic of the planispiral forms, and is a symmetrical interiomarginal aperture in the final chamber, just above the peripheral margin of the previous whorl. It may be extremely high as in *Clavigerinella*, triradial as in *Hantkenina*, or a low arch as in *Hastigerinoides*.

SPIRO-UMBILICAL: An interiomarginal aperture extending from the umbilicus to the periphery and finally on to the spiral side; the most extensive aperture found in trochospiral forms, e.g., *Hastigerinella*.

Secondary Apertures

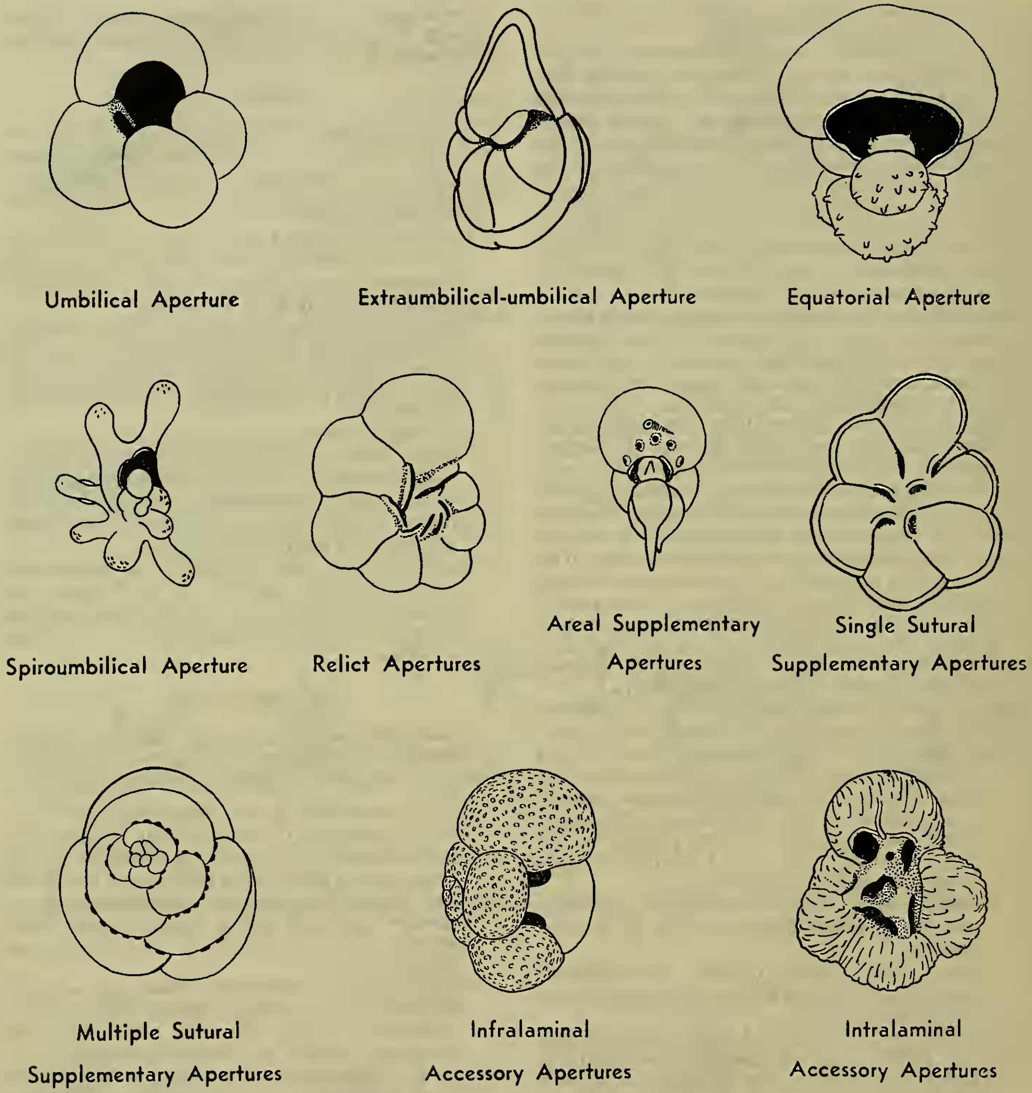
These include smaller openings which are developed in addition to the primary aperture, but in specialized forms may completely replace the primary aperture.

RELICT APERTURES: In the Planomalininae the umbilical portions of the equatorial aperture may not be covered by succeeding chambers, but remain open as short radial slits around the umbilicus. Even when they are secondarily closed, the elevated apertural lips or flanges remain visible around the umbilicus, as in *Planomalina* and *Hastigerinoides*.

SUPPLEMENTARY APERTURES: These may occur in addition to the primary aperture and thus are independent of it. In some cases they may completely replace the primary aperture.

  Areal. Supplementary multiple areal apertures are developed in *Cribrohantkenina*. Specimens may be found in which both the primary equatorial aperture and the supplementary areal apertures occur, showing the latter to be of secondary rank.

  Sutural. Sutural supplementary apertures are in general relatively small. They may be single, or one per suture, as in *Rotalipora*, or multiple,



Umbilical Aperture

Extraumbilical-umbilical Aperture

Equatorial Aperture

Spiroumbilical Aperture

Relict Apertures

Areal Supplementary Apertures

Single Sutural Supplementary Apertures

Multiple Sutural Supplementary Apertures

Infralaminal Accessory Apertures

Intralaminal Accessory Apertures

Figure 5.—Apertural types in planktonic Foraminifera.

with many openings along the sutures, as in *Candeina*. They may be restricted to the spiral side as in *Truncorotaloides*, restricted to the umbilical side as in *Rotalipora*, or present on both sides as in *Candeina*.

Accessory apertures: The accessory apertures do not open directly into the primary chambers, but are openings in or under the accessory structures (i.e., bullae and tegilla) found in the planktonic Foraminifera.

Infralaminal accessory apertures. One or more openings along the margins of the accessory structures, e. g., *Catapsydrax*, *Globigerinita*.

Intralaminal accessory apertures. Openings, usually multiple, which pierce the accessory structures, e. g., *Rugoglobigerina*.

Wall of Test

Composition

In the families under consideration, the wall is composed wholly of calcium carbonate (calcite).

Structure

All these planktonic genera have a perforate radial wall structure.

Bronnimann and Brown (1956) stated that the genera of the Globotruncanidae (including some genera here placed in the Globorotaliidae) have granular perforate walls, except for the surface ornamentation of keels, pustules, etc., which are imperforate. Wood (1949) had stated earlier that *Globotruncana* has a perforate radial wall structure, hence we have checked the wall of the various planktonic genera here described, and have found the wall of each to be perforate radial. As noted by Bronnimann and Brown, and earlier by Wood, the ornamentation of these genera, and that of many of the other genera and families of Foraminifera, may consist of apparently imperforate or very finely perforate shell material that is nevertheless quite distinct from the type of material of the imperforate or porcellanous Foraminifera.

Because many workers have had difficulty in correctly determining the wall structure of various Foraminifera, and wrongly determine the shell of some to be granular, we are here giving the method used in these determinations. Wood (1949) gave an excellent summary of the wall characters of many genera and species, but his photographs of entire specimens of Foraminifera, to demonstrate the typical appearance of the different types, have apparently mislead some later workers. As was clearly stated by Wood in his text, however, the wall structure may be quite obscure if entire shells are examined in polarized light, especially if the walls are relatively thick. In this case, either fragmented specimens or thin sections must be used. The former method, being usually the quicker, is as follows: A clean specimen, free from extraneous filling if possible, is placed on a glass slide and gently crushed with pressure of another glass slide above. A drop of oil, of the index of refraction of calcite, is then added, the cover glass replaced above, and a fragment is sought which shows the wall in cross section. In this fragment the radial or granular structure can be easily determined in polarized light. Further details of the appearance of the fragments of various types of wall structure are given by Wood (1949).

Surface

The surface ornamentation is here considered to be of specific importance only. The following terms are in common use in specific descriptions.

SMOOTH: E. g., *Candeina nitida* d'Orbigny.

CANCELLATE: With a honeycomb-like surface, e. g., *Globigerina reticulata* Stache.

SPINOSE: With very fine solid spines, generally elongate, e. g., *Hastigerinella rhumbleri* Galloway.

HISPID: Very fine, short, and hair-like "spines" as in *Globorotalia truncatulinoides* (d'Orbigny).

RUGOSE: Rough irregular ornamentation, which may form ridges, e. g., *Rugoglobigerina rugosa* (Plummer).

BEADED: Small rounded elevations or "beads" which commonly occur along the sutures and keels, but may also occur on the chamber wall as in *Globotruncana arca* (Cushman).

PITTED: Small, generally rounded depressions in the surface of the wall, e. g., *Sphaeroidinella dehiscens* (Parker and Jones).

Evolutionary Trends

By a study of the geologic record in combination with the ontogeny of the species, several evolutionary trends may be noted. In general these trends are largely related to the pelagic nature of the organism, tending on the one hand to develop a lighter test (thus decreasing the specific gravity and so enabling it to float) or to develop a flattened or radial form (thus retarding its sinking by offering increased area of resistance to the water) and on the other hand a tendency to develop a heavier adult test by the addition of more shell material. These tendencies are undoubtedly the result of selective survival, but may be enumerated as follows:

Replacement of a single primary aperture by many smaller openings. This is accomplished in various ways: 1. By the development of lateral relict supplementary apertures, and in *Biglobigerinella* in developing paired apertures. 2. Development of multiple areal supplementary apertures as in *Cribrohantkenina*. 3. Development of sutural supplementary apertures on the spiral side as in *Globigerinoides* and *Truncorotaloides*, on the umbilical side as in *Rotalipora*, or on both spiral and umbilical sides as in *Candeina*. 4. Development of accessory intralaminal or infralaminal apertures as in *Globotruncana* or *Globigerinita*.

Obscuring or covering of the aperture. The simpler forms have relatively uncomplicated and open apertures, but later developments such as the following may obscure the primary apertures: 1. Apertural lips (e. g., *Globorotalia*) or umbilical "teeth" (e. g., *Globoquadrina*). 2. Chamber extensions, e. g., the flanges of *Sphaeroidinella* and tegilla of *Globotruncana*. 3. Accessory structures or bullae, e. g., *Globigerinita*. 4. Enveloping final chambers, e. g., *Orbulina*. 5. Enfolding of chambers by development of streptospiral coiling, e. g., *Pulleniatina*.

Tendency to develop a spherical test: 1. By means of enveloping chambers, e. g., *Orbulina*. 2. By becoming streptospiral in development, e. g., *Pulleniatina*. 3. By much inflated chambers in planispiral genera, e. g., *Hastigerina*. 4. By becoming high spired in trochospiral genera, e. g., *Globigerinoides*.

Tendency to develop a radial form: 1. By development of radial elongate chambers as in *Hastigerinella*, *Hantkenina aragonensis*, and *Rugoglobigerina scotti*.

2. By development of elongate true spines as in living *Globigerina, Hastigerina, Globigerinoides,* and *Hastigerinella.*

Coiling ratios. This is one apparent evolutionary trend which does not directly affect the pelagic nature of the organism.

As shown by Bolli (1950, p. 82 and 1951, p. 139) the trochospiral genera may develop a preference for sinistral or dextral coiling. Early representatives of a species or group of closely related species may show random coiling, with sinistral and dextral specimens in approximately equal numbers. The stratigraphically younger specimens studied prefer a single direction almost to the exclusion of the other, and this may be either sinistral or dextral, according to the species concerned. These results have been obtained with species of *Rotalipora, Globorotalia* and *Globotruncana.* Similar tendencies, though less distinct, have also been observed in several species of *Globigerina, Globigerinoides* and *Catapsydrax.* Once a preferred direction of coiling is established, it is generally persistent as in all species of *Globotruncana* and in the *Globorotalia fohsi* group, or a rapid change to the opposite direction may take place, indicating possible ecological changes, as in *Globorotalia menardii* (Bolli, 1951) and *Globorotalia truncatulinoides* (Ericson, G. Wollin and J. Wollin, 1954). In rare cases a return to random coiling has been observed in late evolutionary stages, shortly before the extinction of the genus, as in certain related groups of species of *Rotalipora.* All known species of *Globotruncana* and *Rugoglobigerina* tend to develop an almost exclusive preference for dextral coiling. On the other hand, many species of *Globorotalia* develop predominantly sinistral coiling in their later stages, as do some mid-Tertiary species of *Globigerina, Globoquadrina* and *Globigerinoides.* However, the type species of *Catapsydrax,* originally named *Globigerina dissimilis,* prefers a dextral coiling (text-figs. 6, 7).

Bolli (1951, p. 142) further stated that "it appears unlikely that a species with random coiling in its early phylogenetic stage can be genetically related to a stratigraphically older species which shows a distinct preferential direction of coiling in its later stages".

An interesting study in the coiling direction of living and subrecent *Globorotalia truncatulinoides* (d'Orbigny) was made by Ericson, G. Wollin, and J. Wollin (1954) from a study of specimens found in deep sea cores. They found three great provinces of the north Atlantic defined by populations with a dominance of one or the other coiling direction. The northeast quadrant of the north Atlantic shows a dominance of dextral coiling. A central zone of sinistral coiling extends from northwest Africa to North America. The third province is equatorial, extending through the Caribbean and Gulf of Mexico and around the Florida Straits, and contains again dominantly dextrally coiled specimens (text-fig. 8). Near the boundaries of these zones, coiling is almost random.

An examination of a number of cores showed that there was also a variation in coiling direction with time. Two cores from the area with a present day dominant sinistral coiling, showed that sinistral coiling is exceptional in this region, for during deposition dextral coiling was dominant 80 percent of the time. Two swings to the left of short duration were noted in both cores, affording an excellent possibility for correlation.

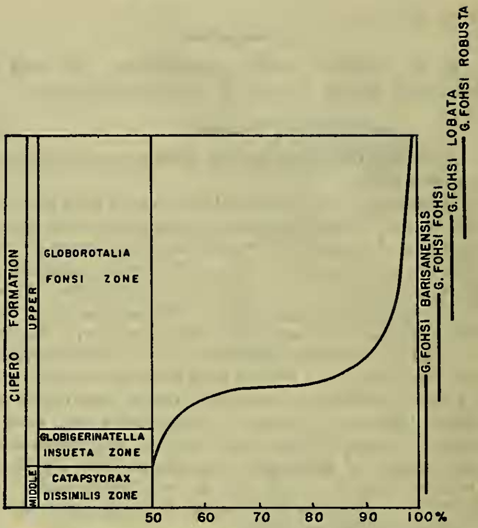


FIGURE 6.—Percentage of sinistral specimens of the *Globorotalia fohsi* group in the Miocene Cipero formation of Trinidad, showing evolution from random coiling to a sinistral dominance with time. (Modified after Bolli, 1950).

Core evidence shows that the Recent province of sinistral coiling dominance has been in existence for at least 2,000 years and probably much longer. Equatorial cores show that the southern province of dextral coiling has existed continuously for at least some tens of thousands of years. There is no physical barrier between these provinces and the species distribution is continuous. Therefore, some unknown environmental factor or selective process must favor the coiling direction dominance in these provinces.

Vašíček (1953) also made a study of coiling ratios, based on the species *Globorotalia scitula,* both in time and regionally. He also concluded that the change in ratio was due to an unknown change in life environment, but that the coiling ratios were extremely useful in correlations within the Moravian Tortonian, where no species suitable for zoning had been found.

Other genera, namely *Spirillina* and *Discorbis,* were shown by Myers to have the direction of coiling related to the alternation of generations, one generation being dextral, the other sinistral. However, other species show a variation of coiling in the megalospheric forms.

It was suggested by Vašíček (p. 413) that the coiling might be related to the reproductive process of "plastogamy." Myers' work on life cycles showed the

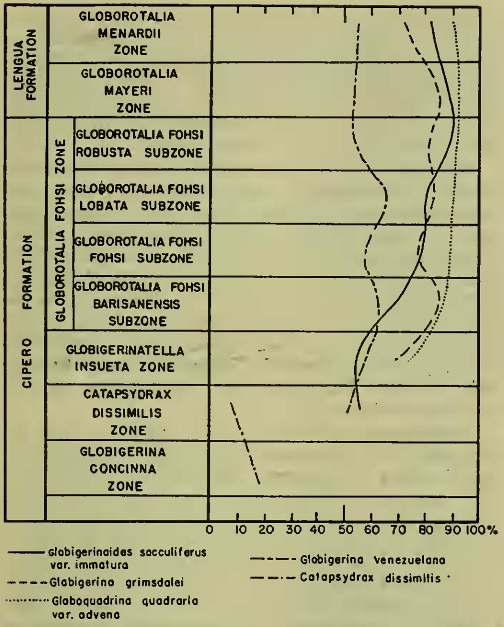


FIGURE 7.—Percentage of sinistral coiling of some Oligocene-Miocene Orbulinidae, showing dominantly sinistral coiling in later development of certain species of *Globigerina*, *Globigerinoides*, and *Globoquadrina*, and dominantly dextral coiling of *Catapsydrax*. (Modified after Bolli, 1951).

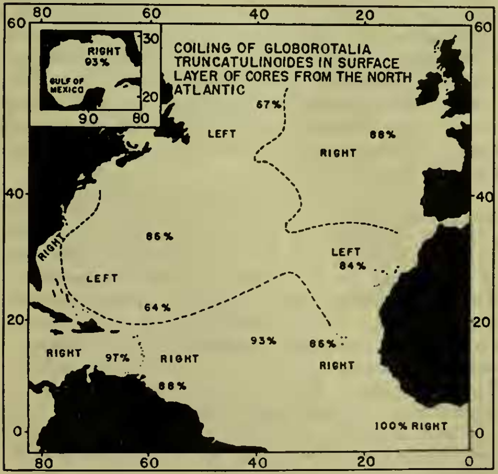


FIGURE 8.—Provinces of dominantly sinistral and dextral coiling of living *Globorotalia truncatulinoides* populations. (After Ericson, G. Wollin and J. Wollin, 1954).

syzygy of megalospheric individuals before the production of the gametes of the sexual generation. This syzygy in the case of *Patellina* was thought to ensure completion of the reproductive processes, as the gametes were amoeboid and nonflagellate. However, other species also show syzygy which do develop flagellate gametes. The coiling direction might facilitate this process, as firm adherence of two tests by their umbilical sides is possible only between individuals of the same direction of coiling. According to Vašíček, the extremes in coiling ratios may thus be due to absolute dependence of the reproductive processes upon such syzygy, during relatively unfavorable conditions, and the fluctuations noted in cores may be due to mixing of populations from another province. In the Moravian region, the coiling ratio curves were somewhat different in the deeper portions of the basin, suggesting the possibility of an influence of temperature.

These theories can only be suggested on the basis of fossil material and to date very little experimental work has been done on life histories and processes of planktonic Foraminifera, due to the considerable difficulty encountered in propagating them under controlled laboratory conditions.

Systematics

Historical Summary

In the classification of d'Orbigny, based solely upon chamber shape, the planktonic genera would fall into four of his seven orders. *Orbulina* would be placed in the Monostègues, or single chambered forms. *Globigerina* and other trochospiral forms would belong to the Hélicostègues (or helically coiled forms), *Cassigerinella* (though then as yet unknown) would have been placed with *Cassidulina* in the Entomostègues and *Sphaeroidinella* in the Agathistègues.

Carpenter (1862) included in the family Globigerinida all coarsely perforate forms, considering *Orbulina* to be the ancestral and simplest form. However, in the Globigerinida he also included with the Globigerinae the arenaceous Textularinae, the *Bulimina* group (with complex internal tubes), and the Rotalinae (with complex canal systems); so that his "coarsely perforate" family included those with perforations of widely differing character, origin, and structure.

Brady (1884) restricted the Globigerinidae to include only *Globigerina*, *Orbulina*, *Hastigerina*, *Pullenia*, *Sphaeroidina*, and *Candeina*. Other planktonic forms were referred to *Pulvinulina* [*Globorotalia*] in the Rotaliidae.

Cushman (1928) separated the then described genera which are included in the present study, into three families, the Globigerinidae, Globorotaliidae, and Hantkeninidae. He included in the family Globigerinidae the subfamilies Globigerininae, Orbulininae, Pulleniatininae, and Candeininae. The first of these subfamilies was quite inclusive, with genera of many varying characters, some of which are here placed in the family Hantkeninidae. Each of the last three subfamilies were relatively exclusive, being either monotypic or including only two genera. The Globorotaliidae included both *Globorotalia* and *Globotruncana*, here separated in two families, as well as *Cycloloculina* and *Sherbornina*. The latter two bear no relation to these planktonic Foraminifera. In the Hantkeninidae he also originally included *Mimosina* and *Trimosina* which are completely unrelated to these planktonic families.

Cushman's family and subfamily descriptions were extremely generalized. For example, the family diagnoses for the Globigerinidae and Rotaliidae could be interchanged without loss of meaning. In later editions of his text, *Mimosina* and *Trimosina* were removed from the Hantkeninidae, and *Schackoina* and *Cribrohantkenina* were added. The Globorotaliidae remained the same, with the addition of *Rotalipora* and two superficially similar but non-planktonic genera *Globorotalites* and *Cribrogloborotalia* (see summary of classifications, below).

Galloway (1933) placed *Hantkenina* in the Nonionidae, because of the planispiral coiling, and *Globorotalia* in the Rotaliidae. He recognized the family name Orbulinidae as having priority over the Globigerinidae, and included in it many of the forms placed in the latter by Cushman, as well as *Globotruncana* and *Neocribrella* and three "doubtful Foraminifera" *Calpionella*, *Oligostegina* and *Disphoeridium*.

In 1942, Brotzen subdivided the rotaliform Foraminifera into the Nonionidae (all planispiral genera), Rotaliidae (with the conical turbospiral genera), Valvulineriidae (for the lenticular formed genera), and Epistominidae (also turbospiral lenticular, but with a sharply angled periphery, commonly with both an interiomarginal aperture and an areal exteriomarginal aperture). He included within the Valvulineriidae the subfamilies Valvuleriinae, Cibicidinae, Globigerininae, and Globotruncaninae. However, the name Anomalinidae Cushman takes precedence over Cibicidinae, and the name Globorotaliinae has precedence over Globotruncaninae. Furthermore, Orbulinidae has priority over Globigerininae, and all of these names—Anomalinidae, Orbulinidae, and Globorotalidae—take precedence over the name Valvulineriidae.

Glaessner (1948) placed the Hantkeninidae as a subfamily within the Globigerinidae, and his Globorotaliidae was restricted to include only *Globotruncana* and *Globorotalia*, being separated from the Globigerinidae largely on the basis of the compressed trochospiral form and the carinate periphery.

In 1949 the important study of wall structures in the Foraminifera by Wood showed that the Globigerinidae, Hantkeninidae, and Globorotaliidae (including *Globotruncana*) all possessed a perforate radial wall structure. The Nonionidae were found to have a perforate granular wall structure. Thus the apparent similarity in planispiral coiling in the Hantkeninidae and Nonionidae is due to convergence and these groups are not closely related, as considered by Galloway.

Bermudez (1952) however, again placed the Hantkeninidae (reduced to a subfamily) in the Nonionidae. *Globorotalia* and *Turborotalia* (here included with *Globorotalia*) he placed with many other non-planktonic genera in the subfamily Valvulineriinae, family Rotaliidae, apparently following Brotzen. However, if this group of genera were to be placed in the same subfamily, the name Globorotaliidae Cushman 1927 would necessarily have precedence, as noted above.

Globotruncana, *Praeglobotruncana*, *Truncorotalia* (here considered synonymous with *Globorotalia*), and *Thalmanninella* (here considered a synonym of *Rotalipora*) were separated by Bermudez into the subfamily Globotruncaninae, although he did not include *Globorotalia*, as had Brotzen. *Ticinella* (here included in *Rotalipora*) and *Rugoglobigerina* were placed by Bermudez in the Globigerinidae. *Rotalipora* itself was placed in the Cymbaloporidae, following the suggested relationship of these genera referred to by Brotzen, although Brotzen had included *Rotalipora* and *Cymbalopora* in the Globotruncaninae.

Bronnimann and Brown (1956) recently elevated the subfamily Globotruncaninae to family rank, and included within it 12 genera. They stated (p. 526) that: "No single morphologic character yet known to us is sufficient to separate all of these twelve genera from some other families of Foraminifera, such as the Globorotaliidae or the Globigerinidae." Within the family they included genera with either apertural cover plates [tegilla], supplementary apertures on the ventral side, a surface ornamentation of discontinuous costellae, or a single- or double-keeled periphery. These characters, however, are of variable taxonomic value, and a more restricted definition of the family seems advisable. The classification used in the present work considers the apertural characters to be of the greatest family significance, and excludes from the Globotruncanidae all genera which do not have an umbilical aperture and umbilical tegilla. The surface ornamentation (such as keels, nodes, and costellae) are variable characters within a genus and are of specific value only. The genera with supplementary apertures on the umbilical side are here placed in the Globorotaliidae, as they all have a visible primary extraumbilical-umbilical aperture like that of *Globorotalia*.

Within their family Globotruncanidae Bronnimann and Brown have thus placed the genera *Hedbergina* (a probable synonym of *Praeglobotruncana*), *Praeglobotruncana*, *Ticinella* and *Thalmanninella* (two synonyms of *Rotalipora*), and *Rotalipora*, all of which, because of the extraumbilical position of the primary aperture, we place in the family Globorotaliidae. *Globotruncana* and *Rugoglobigerina* are considered by both classifications to belong to the Globotruncanidae. In addition, Bronnimann and Brown placed within their family Globotruncanidae as distinct genera *Plummerita*, *Trinitella* and *Kuglerina* (all synonyms of *Rugoglobigerina*) and *Rugotruncana* and *Bucherina* (synonyms of *Globotruncana*).

Hofker (1956, p. 313) placed in the "family Marginolamellidae" (a family name which he had proposed, but which is invalid as it is not based on the name of a type genus, and which is preoccupied by the Globotruncaninae of Brotzen, 1942), the "new" subfamily Globotruncaninae (which was proposed by Brotzen, 1942, and is not new with Hofker), which is comprised of four genera, *Thalmanninella* Sigal, 1948, *Rotalipora* Brotzen, 1942, *Globotruncana* Cushman, 1927, and a new genus, *Marginotruncana* Hofker. *Thalmanninella* is here shown to be a synonym of *Rotalipora*, which belongs to the family Globorotaliidae, and *Marginotruncana*, as based on the type species selected by Hofker, is a true *Globotruncana* (see below under the description of that genus), although Hofker also included other unrelated species in his proposed genus, including species of typical *Praeglobotruncana*, *Rotalipora*, and *Abathomphalus*.

A summary of the principal classifications is given below:

Galloway 1933

- Orbulinidae Schultze, 1854
  - Globigerina d'Orbigny
  - Neocribrella Cushman
  - Globotruncana Cushman
  - Pulleniatina Cushman
  - Candeina d'Orbigny
  - Hastigerina Thomson
  - Orbulina d'Orbigny
- Pegidiidae Heron-Allen and Earland, 1928
  - Sphaeroidinella Cushman
- Rotaliidae Reuss, 1860
  - Globorotalia Cushman
- Nonionidae Reuss, 1860
  - Hantkenina Cushman

Cushman 1948

- Globigerinidae
  - Globigerininae
    - Globigerina d'Orbigny
    - Globigerinoides Cushman
    - Globigerinatella Cushman and Stainforth
    - Globigerinelloides Cushman and ten Dam
    - Globigerinella Cushman
    - Hastigerina Thomson
    - Hastigerinella Cushman
  - Orbulininae
    - Orbulina d'Orbigny
  - Pulleniatininae
    - Pulleniatina Cushman
    - Sphaeroidinella Cushman
  - Candeininae
    - Candeina d'Orbigny
    - Candorbulina Jedlitschka
- Hantkeninidae
  - Schackoina Thalmann
  - Hantkenina Cushman
  - Cribrohantkenina Thalmann
- Globorotaliidae
  - Globotruncana Cushman
  - Globorotalia Cushman
  - Globorotalites Brotzen
  - Rotalipora Brotzen
  - Cribrogloborotalia Cushman and Bermudez
  - Cycloloculina Heron-Allen and Earland
  - Sherbornina Chapman

Bermudez 1952

- Rotaliidae
  - Valvulineriinae
    - Globorotalia Cushman
    - Globorotalites Brotzen
    - Turborotalia Cushman and Bermudez
    - Globoquadrina Finlay
    - Cribrogloborotalia Cushman and Bermudez
  - Globotruncaninae
    - Praeglobotruncana Burmudez
    - Thalmanninella Sigal
    - Globotruncana Cushman
    - Truncorotalia Cushman and Bermudez
- Cymbaloporidae
  - Rotalipora Brotzen
- Nonionidae
  - Hantkenininae
    - Schackoina Thalmann
    - Hantkenina Cushman
    - Sporohantkenina Bermudez
    - Applinella Thalmann
    - Aragonella Thalmann
- Globigerinidae
  - Globigerininae
    - Globigerina d'Orbigny
    - Globigerinoides Cushman
    - Hastigerinella Cushman
    - Hastigerinoides Bronnimann
    - Globigerinella Cushman
    - Biglobigerinella Lalicker
    - Trinitella Bronnimann
    - Hastigerina Thomson
    - Globigerinatheka Bronnimann
    - Globigerinelloides Cushman and ten Dam
    - Globigerinita Bronnimann
    - Globigerinoita Bronnimann
    - Rugoglobigerina Bronnimann
    - Plummerita Bronnimann
    - Ticinella Reichel
    - Globigerinatella Cushman and Stainforth
  - Orbulininae
    - Orbulina
  - Pulleniatininae
    - Pulleniatina Cushman
    - Sphaeroidinella Cushman
  - Candeininae
    - Candorbulina Jedlitschka
    - Candeina d'Orbigny

Bolli, Loeblich, and Tappan 1957

- Hantkeninidae Cushman, 1927
  - Planomalininae Bolli, Loeblich and Tappan, new subfamily
    - Globigerinelloides Cushman and ten Dam
    - Planomalina Loeblich and Tappan
    - Hastigerinoides Bronnimann
    - Biglobigerinella Lalicker
  - Hantkenininae Cushman, 1927
    - Schackoina Thalmann
    - Hantkenina Cushman
    - Cribrohantkenina Thalmann
  - Hastigerininae Bolli, Loeblich, and Tappan, new subfamily
    - Hastigerina Thomson
    - Clavigerinella Bolli, Loeblich, and Tappan
  - Cassigerinellinae Bolli, Loeblich, and Tappan, new subfamily
    - Cassigerinella Pokorný

- Globorotaliidae Cushman, 1927
    - Praeglobotruncana Bermudez
    - Rotalipora Brotzen
    - Globorotalia Cushman
    - Truncorotaloides Bronnimann and Bermudez
- Globotruncanidae Brotzen, 1942
    - Abathomphalus Bolli, Loeblich, and Tappan
    - Rugoglobigerina Bronnimann
    - Globotruncana Cushman
- Orbulinidae Schultze, 1854
    - Globigerininae Carpenter, 1862
        - Globigerina d'Orbigny
        - Globoquadrina Finlay
        - Hastigerinella Cushman
        - Globigerinoides Cushman
        - Sphaeroidinella Cushman
        - Pulleniatina Cushman
    - Orbulininae Schultze, 1854
        - Globigerapsis Bolli, Loeblich, and Tappan
        - Porticulasphaera Bolli, Loeblich, and Tappan
        - Candeina d'Orbigny
        - Orbulina d'Orbigny
    - Catapsydracinae Bolli, Loeblich, and Tappan, new subfamily
        - Catapsydrax Bolli, Loeblich, and Tappan
        - Globigerinita Bronnimann
        - Globigerinoita Bronnimann
        - Globigerinatheka Bronnimann
        - Globigerinatella Cushman and Stainforth

The families of planktonic genera have been separated by earlier classifications variously on the external form of the test, type of coiling, or a combination of characters of varied importance, including surface ornamentation; and the families have been considered to properly include genera of differing wall structure, apertural characters, etc. These bases for separation have obviously not proved entirely successful, as certain genera have been placed in one family after another by successive workers, while the family and subfamily limits have varied widely in the different classifications.

Furthermore, little attention has been paid in the past to the priority status of family and subfamily names. Under the Rules of Nomenclature the family and subfamily names are treated as equal for purposes of priority. For this reason, the oldest name used for either a family or subfamily, based on a genus placed within the family, must be used as the valid family name, and if the family is divided into subfamilies, the subfamily containing the type genus of the family must also bear the name based on that genus.

Bases for Classification

MORPHOLOGIC EVIDENCE: In the present classification the morphology of the test is used as the primary basis. The families under consideration here are all alike in possessing a calcareous, perforate-radial wall, hence all genera with perforate granular walls are excluded. Similarly, these radial-walled genera cannot be placed within families characterized by granular walls.

The apertural position is considered second in importance only to the wall composition and structure. It is always a constant character in the adult, and one of the few characters which does not change with environmental changes. It may change in size and position in the ontogeny of the individual, but these changes are always the same in each individual of the species. Thus, they are also extremely valuable in showing relationships, for the aperture in the young stage is like that of the ancestral form, and there may be intermediate ancestral characters also shown in the gradual development of the adult characters.

The type of chamber development, primarily the type of coiling, is third in systematic importance within these groups. Thus, the Orbulinidae, Globorotaliidae, and Globotruncanidae, all have a basic trochospiral coiling. Specialized genera may develop modifications, but trochospiral coiling is nonetheless present in their early ontogenetic stages. Similarly the Hantkeninidae have a basically planispiral development.

The characteristic modifications of apertures, changes from simple to multiple apertures, from open to covered, or from an interiomarginal to an areal position, are fourth in importance.

Modifications of the chambers and the resultant test form are fifth in importance. In the planktonic groups this is generally expressed in one of two ways, a tendency to develop a radially expanding test or a tendency to develop a globular test.

Last are the more detailed characters of size and relative proportions of test, chambers, and apertures and ornamentation.

EVIDENCE FROM ONTOGENY: The well known biologic theory that "Ontogeny recapitulates phylogeny," has also been a basis used in the present classification.

Dissections of many of the species have shown that they pass through early stages that resemble other genera. For example, specimens of the genus *Globigerinoita* pass through an early *Globigerina*-like stage, then a *Globigerinoides* stage, and finally develop the adult characters peculiar to their own genus. This ontogenetic development shows the family relationship between these genera, although the adult characters of *Globigerinoita*, in particular the development of the secondary bullae over the apertural openings, are considered of sufficient taxonomic value to place this genus in a separate subfamily. Similarly the early trochospiral development and *Globigerina*-like umbilical aperture of the young stage of *Hastigerinella* suggest that it should be placed with *Globigerina* rather than with *Hastigerinoides*, which it resembles only in the pelagic adaptation of developing radial-elongate chambers. This latter character is obviously due to convergence, as a similar flattening or spreading in a plane is developed merely as an aid to flotation in many other groups of pelagic animals.

STRATIGRAPHIC DISTRIBUTION: In order to devise a logical classification, the geologic occurrence should also be considered. The ancestral forms should of course be those found earliest in the geologic record, although in some proposed classifications certain "ancestral types" were found only in relatively young strata.

Unfortunately, published records are not always reliable. Foraminifera have been recorded at times from misdated horizons, or in other instances from beach sands or Recent deposits which also include reworked fossil material. In other instances the too-wide limits set for genera and species suggest a much wider geologic range than is actually the case. Thus, in order to use stratigraphic occurrence as a tool in classification, many of these records have had to be critically re-examined.

The tabulation in text-figure 9 shows the stratigraphic ranges of the genera of planktonic Foraminifera as here defined. As can be seen, many of the genera are more restricted in geologic range than has hitherto been suspected. The actual placement of the various species is not attempted in the present paper, but will appear in later publications of this series.

Summary

In the present revision the following characters have been used for classification:

FAMILY CHARACTERS: The wall composition and structure, general chamber arrangement (i. e., type of coiling), basic position of primary aperture (in adult of simpler forms, in ontogeny of specialized forms).

SUBFAMILY CHARACTERS: Presence or absence of apertural modifications, modifications in chamber arrangement (i. e., changes in type of coiling) and presence or absence of chamber modifications.

GENERIC CHARACTERS: Position, shape and character of aperture in the adult, presence or absence of chamber modifications, and general form and development of the test.

SPECIFIC CHARACTERS: Size; relative proportions of test, chambers and aperture, etc.; and surface ornamentation.

The resultant classification here presented is similar to that of Cushman in recognizing the families Hantkeninidae, Globorotaliidae and Orbulinidae (which has priority over the name Globigerinidae). The main differences lie in the separation of *Globotruncana* from the Globorotaliidae and *Rugoglobigerina* from the Globigerininae into a separate family—the Globotruncanidae (which has been done by Bronnimann and Brown, 1956, although they also included various genera here placed in the Globorotaliidae); the recognition of three new subfamilies in the Hantkeninidae—the Planomalininae, Hastigerininae and Cassigerinellinae—the family being enlarged to include all planispiral planktonic genera with equatorial apertures and thus including some forms placed by Cushman and others in the Globigerinidae; the suppression of two subfamilies of the Orbulinidae—the Candeininae and Pulleniatininae—their type genera being placed in other previously described subfamilies; and the naming of the new subfamily Catapsydracinae for the orbulinids with apertural covers.

Systematic Descriptions

Family Hantkeninidae Cushman, 1927

TYPE GENUS: *Hantkenina* Cushman, 1924.

Coiling of test trochospiral or planispiral or enrolled biserial; chambers spherical, ovate, elongate, clavate or tubulospinate; wall calcareous, perforate, radial in structure; primary aperture symmetrical and equatorial, paired or multiple, may have relict or areal secondary apertures.

Planomalininae Bolli, Loeblich, and Tappan, new subfamily

TYPE GENUS: *Planomalina* Loeblich and Tappan, 1946.

Coiling planispiral; chambers spherical, ovate, clavate or angular rhomboid; primary aperture equatorial or symmetrically paired, with umbilical portions of successive apertures remaining as relict secondary apertures.

RANGE: Cretaceous.

Genus Globigerinelloides Cushman and ten Dam, 1948

PLATE 1, FIGURES 1a, b

Globigerinelloides CUSHMAN and TEN DAM, Contr. Cushman Lab. Foram. Res., vol. 24, p. 42, 1948.

TYPE SPECIES: *Globigerinelloides algeriana* Cushman and ten Dam, 1948. Fixed by original designation and monotypy.

Test free, planispiral, evolute to nearly involute, biumbilicate; early chambers subglobular, later chambers ovate and flaring out in a more evolute coil, with a flange extending on each side back to the previous whorl, somewhat curved backward at the umbilical margin; sutures distinct, depressed, radial in the early coil, later sigmoid; wall calcareous, finely perforate, radial in structure, surface smooth or roughened; aperture interiomarginal, an equatorial arch.

REMARKS: *Globigerinelloides* resembles *Hastigerina* Thomson in being planispiral with an equatorial aperture, but in *Globigerinelloides* the later chambers have

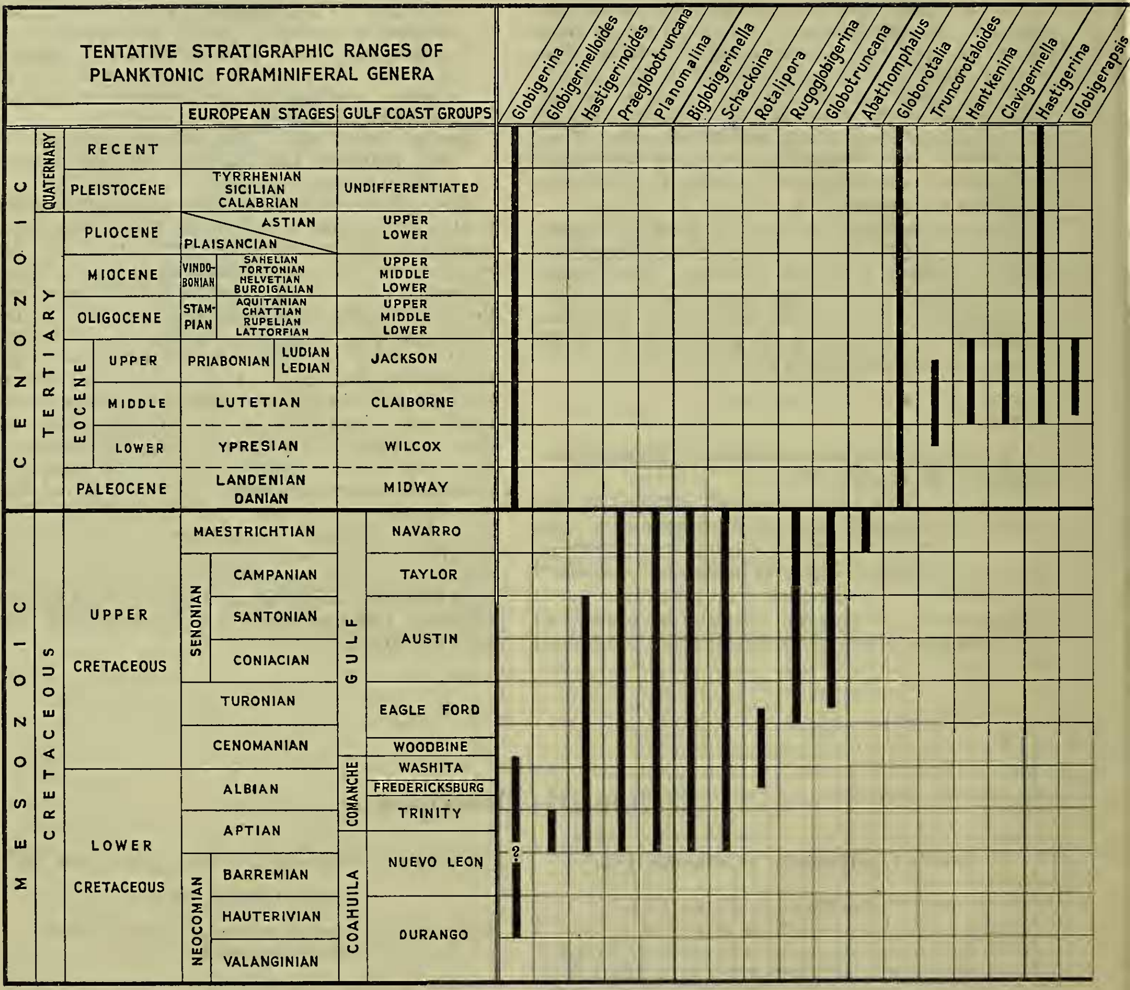
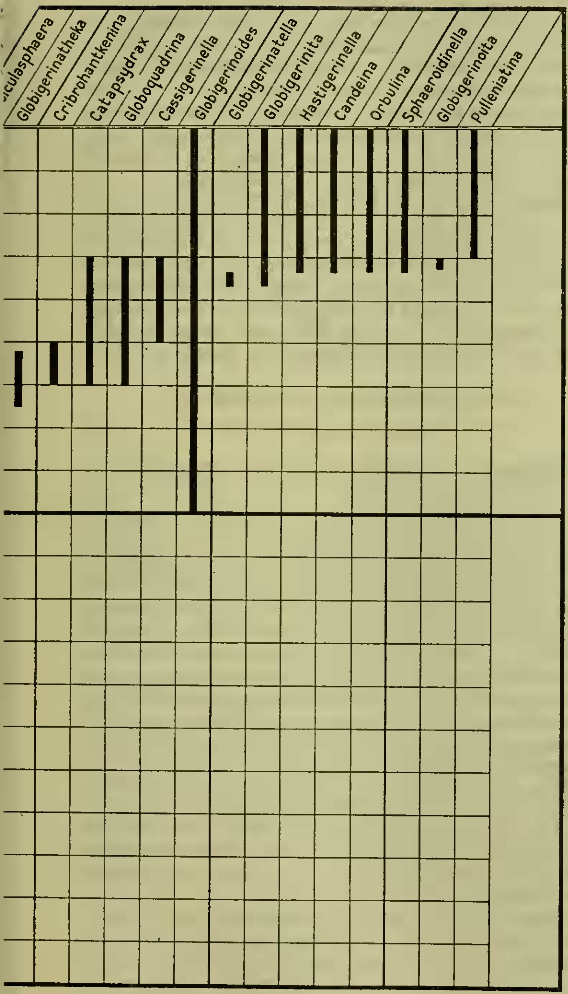


Figure 9.—Tentative stratigraphic ranges of planktonic foraminiferal genera.

an umbilical extension on each side, connecting the chambers to the previous whorl. In addition, there is a peculiar curvature, almost sinuate, of the later chambers and sutures near the umbilicus, and a tendency toward an uncoiled later stage.

In a new species of *Biglobigerinella*, described later in the present paper, an ontogenetic sequence is shown from a form much like *Globigerinelloides algeriana*, to a stage with two small lateral apertures, and finally to a bichambered end stage. A careful study of material from the type horizon of *Globigerinelloides* could determine whether or not a similar development is present in that form. If so, *Biglobigerinella* Lalicker would become a synonym of *Globigerinelloides*, for the present generic name was published three months prior to *Biglobigerinella*. Until definite evidence is available both genera are provisionally recognized.

Types and occurrence: Cushman and ten Dam (1948, p. 42) recorded this genus from the Upper Cretaceous of Djebel Menaouer in western Algeria.



Glintzboeckel and Magné (1955, p. 154) have shown that *Globigerinelloides algeriana* occurs about 200 meters below an Aptian (Upper Gargasian) ammonite assemblage and it is regarded by them as a "good guide fossil for the Aptian of North Africa."

Figured paratype (Cushman Coll. 56790) from greenish blue marls of Aptian age, Djebel Menaouer, between Relizane and Uzes-le-Duc, western Algeria. Collected by A. ten Dam.

RANGE: Aptian.

Genus Planomalina Loeblich and Tappan, 1946 [1]

PLATE 1, FIGURES 2a–3b

Planomalina LOEBLICH and TAPPAN, 1946, Journ. Paleontol., vol. 20, No. 3, p. 257, 1946.

TYPE SPECIES: *Planomalina apsidostroba* Loeblich and Tappan, 1946. Fixed by original designation and monotypy.

Test free, planispiral, biumbilicate, involute to partially evolute, lobulate in outline; chambers spherical to ovate to angular rhomboid; sutures radial, straight or curved, elevated or depressed; wall calcareous,finely perforate, radial in structure, surface smooth or ornamented with nodes and keel; aperture interiomarginal, an equatorial arch, with lateral extensions reaching back at either side to the septum at the base of the chamber, the lateral umbilical portions of successive apertures remaining open as supplementary relict apertures after the equatorial portion is covered by the succeeding chambers, these small relict slits and prominent bordering lips giving a characteristic appearance to the umbilical region.

REMARKS: Originally believed to be related to *Anomalina* because of the relatively coarsely perforate, planispiral test, *Planomalina* is now shown to possess lateral relict apertures in addition to the primary interiomarginal equatorial aperture, which with the planispiral plan of growth suggests a relationship to such planktonic genera as *Hastigerinoides*. Another excellently preserved species here described, which lacks the surface ornamentation of the type species, shows even more clearly the relationship to this group. As *Planomalina* is the most primitive of those with relict apertures it is here made the type genus for the subfamily Planomalininae.

Planomalina differs from *Biglobigerinella* Lalicker in having extremely prominent relict apertures, and in having only a single primary aperture, whereas *Biglobigerinella* develops a paired primary aperture, and may have paired final chambers as well. If differs from *Globigerinelloides* Cushman and ten Dam in lacking the sinuately curved umbilical chamber extensions, and in possessing relict apertures.

TYPES AND OCCURRENCE: Holotype of *Planomalina apsidostroba* Loeblich and Tappan (Cushman Coll. 45667) from the Main Street formation, in a road cut on the south side of the Godley-Cleburne road, just uphill from the bridge across Nolan's River, 4.8 miles southeast of Godley, locality HTL–102, sample 418,

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[1] After the present paper had been sent to press, the genus *Biticinella* Sigal, 1956, was described, with *Anomalina breggiensis* Gandolfi as type species. *Biticinella*, superficially very similar to *Planomalina*, was defined as a "morphologic genus" related to the *Ticinella-Thalmanninella-Rotalipora* group in being slightly asymmetrical, and in having accessory intraumbilical apertures, at the posterior border of the chambers. In *Planomalina* the umbilical slits are at the forcward margins of the chambers and are relict apertures, i. e., the exposed umbilical remnants of the primary aperture. *Biticinella* thus may be related to *Rotalipora* of the family Globorotaliidae. If the supplementary apertures in *Biticinella* should prove to be relict apertures, however, the genus *Biticinella* would probably become a synonym of *Planomalina*.

Johnson County, Texas. Collected 1940 by H. T. and A. R. Loeblich, Jr.

Figured hypotype (USNM P5394) from a 1-foot sample of grayish clay in the upper Paw Paw formation, 7½ feet below the contact with the overlying Main Street formation, on the south side of the road at the western edge of the Federal Narcotic Farm, southeast of Fort Worth, locality HTL–55, Tarrant County, Texas. Collected 1939 by H. T. and A. R. Loeblich, Jr.

Range: Aptian to Maestrichtian.

Planomalina caseyi Bolli, Loeblich, and Tappan, new species

Plate 1, Figures 4a–5b

Test free, planispiral, biumbilicate, involute to partially evolute, lobulate in outline; chambers spherical to ovate, 7 to 9 in the final whorl, early ones closely coiled, later ones with a tendency to become evolute in some specimens, sutures radial, gently curved, moderately depressed; wall calcareous, finely perforate, surface smooth; aperture interiomarginal, a broad low equatorial arch, with lateral extensions reaching back on the umbilical margin of the chamber to the septum at the base of the chamber, the lateral slitlike extensions bordered above by a distinctly upturned lip, the umbilical portions of the apertures of successive chambers remaining open as relict supplementary apertures beneath the lips after later chambers have covered the primary apertures.

Greatest diameter of holotype 0.31 mm., thickness 0.13 mm. Paratypes range in diameter from 0.18 to 0.39 mm.

Remarks: *Planomalina caseyi*, new species, differs from *Planomalina apsidostroba* Loeblich and Tappan in having more globular and inflated chambers, a smooth rather than carinate periphery and depressed rather than limbate, elevated and beaded sutures. *Planomalina caseyi* is a more primitive form, occurring in somewhat older beds, in the Duck Creek formation of Texas and Oklahoma (mid-Albian) and in the Gault (Albian) of England, whereas the more ornate *P. apsidostroba* is found in the Weno, Paw Paw, and Main Street formations (upper Albian) of Texas.

It differs from *Biglobigerinella barri*, new species, in being about one-half as large, in having fewer and more inflated chambers, in lacking the rugose periphery, and in always having a single primary peripheral aperture, with no development of paired apertures or paired chambers.

The specific name is in honor of Mr. Raymond Casey, Geological Survey of Great Britain, in recognition of his outstanding work on the Lower Cretaceous ammonites and pelecypods and on the stratigraphy of Great Britain.

Types and occurrence: Holotype (USNM P4869), figured paratype (USNM P4870) and unfigured paratypes (USNM P4871 and P4872) from the Albian Gault clay, Brick pit of the London Brick Co., Arlesey, England. Collected 1953 by H. T. and A. R. Loeblich, Jr.

Unfigured paratypes (USNM P5396) from 5½ feet of section, alternating gray shale and marly limestone, 58 feet above the base of the Duck Creek formation, and 6½ feet below the fucoid-bearing basal limestone of the Fort Worth formation, Lower Cretaceous, Albian, on the west bank of the Red River, in the SW¼Sec.22,T.8-S.,R.2E., on the southwest side of Horseshoe Bend, locality HTL–13, Love County, Oklahoma. Collected August 1939 by H. T. and A. R. Loeblich, Jr.

Unfigured paratypes (USNM P5395) from the top 6 feet exposed in the excavation for the Denison Dam, alternating thin limes and yellow brown clays of the Duck Creek formation, 45 feet above the base, north of Denison, Grayson County, Texas. This excavation at the site of the dam for Lake Texhoma is now covered and grassed over. Locality HTL–104, collected July, 1940 by H. T. and A. R. Loeblich, Jr., sample 462–463.

Genus Hastigerinoides Bronnimann, 1952

Plate 1, Figures 6a–10b

Hastigerinoides Bronnimann, Bull. Amer. Paleontol., vol. 34, No. 140, p. 52, 1952.

Type Species: *Hastigerinella alexanderi* Cushman, 1931. Fixed by original designation.

Test free, stellate in appearance, planispiral, biumbilicate, periphery rounded; early chambers globular, later chambers elongate-radial, much produced and tapering or clavate; sutures depressed, radial; wall calcareous, perforate, radial in structure, surface smooth, pitted or finely hispid; primary aperture interiomarginal, equatorial, a simple arch bordered above by a protruding lip, with relict secondary apertures around the umbilical region, representing the umbilical portion of previous apertures, which may remain open or be closed.

Remarks: Bronnimann (1952b, p. 53) stated: "The difference in the shape of the adult chambers is considered to justify the splitting of the genus *Hastigerinella* Cushman into *Hastigerinella* s.s., with club-shaped adult chambers, and *Hastigerinoides* n. subgen. with pointed adult chambers."

Topotype specimens of *Hastigerinella alexanderi* Cushman show occasional club-shaped as well as pointed chambers on a single specimen. Therefore, the chamber shape alone cannot be considered, in this case, a valid separation for genera or subgenera. However, a more important generic character is the type of coiling. The type species of *Hastigerinella*, and therefore of the genus, strictly considered, is trochospiral in development, whereas in *Hastigerinoides* the coiling is planispiral. The aperture of *Hastigerinella* is broad and extraumbilical-umbilical, in the later stages extending farther towards the periphery and even onto the spiral side, but is not a typically equatorial aperture as is the primary aperture of *Hastigerinoides*. The relict secondary apertures also are found only in the latter genus. These differences in coiling and apertural characters are considered a valid basis for elevating *Hastigerinoides* to generic rank.

Types and occurrence: Holotype of *Hastigerinella alexanderi* Cushman (type of *Hastigerinoides*) (Cushman Coll. 15750), figured paratype (Cushman Coll. 15754), figured topotypes (USNM P3920a, b), unfigured topotypes (USNM P3933), and unfigured paratypes (Cushman Coll. 15754a), all from the Austin chalk, clay in road cut between two railroad underpasses (now removed) at the northern edge of Howe, Grayson County, Texas. Holotype and paratypes collected by C. I. Alexander; topotypes collected by A. R. Loeblich, Jr.

Figured topotype of *Hastigerinoides watersi* (Cushman) (USNM P3934) also from the Austin chalk at the same locality, collected by A. R. Loeblich, Jr.

Range: Aptian to Santonian.

Genus Biglobigerinella Lalicker, 1948

Plate 1, Figures 11–12b

Biglobigerinella Lalicker, Journ. Paleontol., vol. 22, p. 624, 1948.

Type species: *Biglobigerinella multispina* Lalicker, 1948. Fixed by original designation and monotypy.

Test free, planispiral, nearly or completely involute, biumbilicate, periphery rounded, peripheral margin lobulate; chambers globular, except for the final one or two which may become broadly ovate, flattened and finally replaced by two paired chambers, one on each side of the plane of coiling, in some species there is a tendency for the chambers of the final whorl to flare out in a less involute coil, with a flange extending back on each side toward the previous whorl, and curving backward at the umbilical margin, as in *Globigerinelloides;* sutures distinct, depressed, radial to curved or even sigmoid; wall calcareous, finely perforate, radial in structure, surface finely hispid to smooth or pitted; aperture an interiomarginal, equatorial, simple low arch in the early stages, in the later paired chambers there is one extraumbilical aperture in each chamber of the final pair.

Remarks: *Biglobigerinella* differs from *Hastigerina* Thomson in the presence of the final paired chambers and double aperture, although it is similar in being planispiral and more or less completely involute.

Types and occurrence: Holotype of *Biglobigerinella multispina* Lalicker (Cushman Coll. 51898), figured paratypes (Cushman Coll. 51899 and 51900), and unfigured paratypes (Cushman Coll. 51897) from the Marlbrook marl (Campanian), 8 feet above the base, 1½ mile north of Saratoga, Howard County, Ark.

Figured hypotype (USNM P3214a) and unfigured hypotypes (USNM P3214) from the upper Taylor marl (Campanian) on the right bank of Onion Creek, just downstream from the bridge at Moore and Berry's crossing, 8½ miles in a straight line southeast of the Capitol in Austin, Travis County, Texas. Collected by H. T. and A. R. Loeblich, Jr.

Unfigured hypotype (USNM P3215) from the Navarro (Corsicana marl), Maestrichtian, exposed in a steep 80-foot slope on the right bank of Onion Creek just east of the bridge (known as Jones' Crossing) on the Austin-Bastrop highway, Travis County, Texas. Collected by A. R. Loeblich, Jr.

Range: Aptian to Maestrichtian.

Biglobigerinella barri Bolli, Loeblich, and Tappan, new species

Plate 1, Figures 13–18b

Test free, planispiral, biumbilicate, nearly involute to evolute; peripheral margin somewhat lobulate; chambers ovate to nearly spherical, 8 to 10 in the final planispiral whorl, in some specimens a smaller low but broad final chamber may cover a double apertured penultimate chamber or there may be a small chamber at each side of the periphery, each covering one of the lateral apertures of the penultimate chamber; sutures distinct, depressed, radial in the early portion, becoming sigmoid in the later stages; wall calcareous, finely perforate, surface distinctly rugose in the early portion, later chambers nearly smooth or pitted; aperture interiomarginal, in the early stage equatorial, a low arch bordered above with a narrow lip, in the later stage there is a double aperture consisting of a small extraumbilical arch at each side of the last chamber, or one to each of the final paired chambers which may extend almost into the umbilicus, each aperture bordered by a lip.

Greatest diameter of holotype 0.49 mm., thickness across paired chambers 0.36 mm. Paratypes range from 0.39 to 0.62 mm. in diameter.

Remarks: *Biglobigerinella barri*, new species, differs from *B. multispina* Lalicker in being larger and more compressed and in having 8 to 10 chambers per whorl instead of only 5 to 6. The chambers are also more nearly globular in *B. multispina*.

The shape and number of the chambers is also similar to *Globigerinelloides algeriana* Cushman and ten Dam, from which the present species differs only in developing a double aperture and finally the double-chambered end stage. This species strongly suggests that *Biglobigerinella* may have arisen from the Aptian genus *Globigerinelloides*.

The specific name is given in honor of Dr. K. W. Barr, in recognition of his work on the geology of Trinidad.

Types and occurrence: Holotype (USNM P4543), figured paratypes (USNM P4544a–e) and unfigured paratypes (USNM P4545) from the Lower Cretaceous (Aptian) Maridale formation, Maridale Estate, east Central Range, Trinidad, B. W. I. Collected by H. H. Renz.

Subfamily Hantkenininae Cushman, 1927

Type genus: *Hantkenina* Cushman, 1924.

Coiling of test trochospiral to planispiral; chambers globular, elongate to tubulospinate; aperture equatorial or areal multiple.

Range: Cretaceous to Eocene.

Genus Schackoina Thalmann, 1932

Plate 2, Figures 1a–2

Schackoina Thalmann, Eclog. Geol. Helvetiae, vol. 25, p. 289, 1932.

Type species: *Siderolina cenomana* Schacko, 1896. Fixed by original designation.

Test free, early portion may be more or less trochospiral, later becoming nearly planispiral; chambers radially elongate with one or more elongate, tapering hollow tubulospines extending outward from the midline of each chamber on the periphery; sutures straight, radial, depressed; wall calcareous, finely perforate, surface smooth or very finely hispid; primary aperture an interiomarginal arch, extraumbilical and tending to become equatorial, may be bordered above by a narrow lip.

Remarks: *Schackoina* differs from *Hantkenina* Cushman in being trochospiral and in having a simple interiomarginal arched aperture, whereas *Hantkeinina* has a triradiate aperture with a high slit extending up the face of the final chamber.

It differs from *Hastigerinoides* Bronnimann in being trochospiral and in having the tubulospines distinctly separated from the main chamber cavity.

Types and occurrence: Figured hypotypes (USNM P4644a, b) and unfigured hypotypes (USNM P4563) of *Schackoina cenomana* (Schacko) from the Cenomanian *Schloenbachia varians* zone; unfigured hypotypes (USNM P4562) from the Cenomanian *Inoceramus crippsi* zone; all from Ziegelei Zeltberg, at Luneburg, southeast of Hamburg, Province Niedersachsen, Germany. Collected by H. T. and A. R. Loeblich, Jr.

Range: Aptian to Maestrichtian.

Genus Hantkenina Cushman, 1924

Plate 2, Figures 3a–8b

Hantkenina Cushman, Proc. U. S. Nat. Mus., vol. 60, art. 30, p. 1, 1924.

Sporohantkenina Bermudez, Mem. Soc. Cubana Hist. Nat., vol. 11, p. 151, 1937. (Type species: *Hantkenina brevispina* Cushman, 1924. Fixed by original designation and monotypy.)

Aragonella Thalmann, Amer. Journ. Sci., vol. 240, pp. 811, 813, 818, 1942. (Type species: *Hantkenina mexicana* Cushman var. *aragonensis* Nuttall, 1930. Fixed by original designation.)

Applinella Thalmann, Amer. Journ. Sci., vol. 240, pp. 812, 813, 819, 1942. (Type species: *Hantkenina dumblei* Weinzierl and Applin, 1929. Fixed by original designation.)

Hantkeninella Bronnimann, Journ. Paleontol., vol. 24, No. 4, p. 399, 1950. (Type species: *Hantkenina alabamensis* Cushman var. *primitiva* Cushman and Jarvis, 1929. Fixed by original designation and monotypy.)

Type species: *Hantkenina alabamensis* Cushman, 1924. Fixed by original designation.

Test free, planispiral, involute, biconvex, biumbilicate; chambers rounded, ovate or radial elongate, generally with a single relatively long and heavy spine at the forward margin of each chamber on the periphery, although they may rarely be lacking on one or more chambers, spines in the plane of coiling; sutures depressed, radial; wall calcareous, finely perforate, radial in structure, surface finely hispid, especially in the area just beneath the aperture on the previous whorl; primary aperture interiomarginal, equatorial, triradiate, two of the "rays" forming a slit across the base of the final chamber face, the third ray arising from the center of this slit and extending up the face toward the peripheral spine, flaring slightly to become rounded at its upper end, the vertical slit bordered laterally by apertural flanges which join above as a narrow lip.

Remarks: In the original description of *Hantkenina*, Cushman stated (1924, p. 1) that it included *Siderolina* of Hantken (not Defrance), and "while they should probably be referred to the Rotaliidae are very different from *Siderolites* or *Calcarina*." In his classification (1927, p. 64) Cushman placed it in a separate family, the Hantkeninidae; he included with it *Mimosina* Millett and *Trimosina* Cushman, and stated (p. 65), "the family is related to the Heterohelicidae."

In later publications (1933, p. 267) *Mimosina* and *Trimosina* were placed by Cushman in the Buliminidae and *Schackoina* Thalmann was placed with *Hantkenina*. Galloway (1933, p. 266) placed *Hantkenina* in the Nonionidae, stating (p. 264) that it "evolved from *Nonion* by developing a long spine on each chamber."

Bermudez defined *Sporohantkenina* in 1937, but the type species selected is congeneric with true *Hantkenina*. Thalmann (1942) defined three new subgenera of *Hantkenina: Cribrohantkenina*, which included Bermudez's forms (but not the *Hantkenina brevispina* of Cushman), *Aragonella*, and *Applinella*.

Cushman's test (1948) did not mention the latter two subgenera, although he raised *Cribrohantkenina* to generic status and stated (p. 328), "Further studies of these forms seem to show that they were derived from the Globigerinidae and were probably pelagic, at least during part of their life history."

Glaessner (1948, p. 149) placed the subfamily Hantkenininae in the family Globigerinidae, and Sigal (1952, p. 235) recognized it as a separate family. Bermudez (1952, p. 108) placed *Hantkenina* and the three subgenera mentioned above in the Hantkenininae, family Nonionidae, apparently following Galloway's earlier suggestion.

Wood (1949, p. 250) showed that *Hantkenina* is perforate radial in wall structure (like the Globigerinidae and Heterohelicidae), whereas the Nonionidae were perforate granular (exclusive of the Elphidiidae, which Cushman placed in the Nonionidae). Therefore, *Hantkenina* and its allies cannot be related to the Nonionidae, and the planispiral development of the two families is merely convergence. It is more probable that this group arose from the Planomalininae or the early Globorotaliidae, for *Schackoina*, developing in the Cretaceous, was trochospiral. The entire family Hantkeninidae may have been derived from an ancestor such as *Praeglobotruncana* of the Globorotaliidae, since many lines of evolution point to a development of planispiral forms from the trochospiral, rather than the converse.

Barnard (1954, p. 384) made a study of the apertural characters of specimens of *Hantkenina* from the Jackson Eocene of Cocoa Post Office, Alabama, showing the ontogenetic development of the multiple aperture of the subgenus *Cribrohantkenina*. He concluded (p. 389): "The sub-genera are arbitrary divisions, and in the opinion of the author the use of them should be discouraged."

We have examined large suites of specimens of many species of *Hantkenina* from many areas and have found none that show a gradation from the simple triradial aperture of *Hantkenina* to the multiple aperture of *Cribrohantkenina*. Furthermore, in our suite of specimens from the area of the Cocoa Post Office the typical *H. alabamensis* is much flatter; the sutures are moderately depressed, straight, and radial; and the periphery is entire. The associated "*Cribrohantkenina bermudezi*" always has more inflated chambers and a lobulate periphery, very deeply constricted sutures; and the rounded openings of the multiple aperture are found even on quite small specimens. We believe, therefore, that Barnard was dealing with more than one species but that all the specimens he used to show a developmental series of apertures belong to *Cribrohantkenina* and do not show a gradation between this genus and *Hantkenina*.

There are other species of the Hantkenininae also present at this locality, and *Hantkenina brevispina* Cushman resembles *Cribrohantkenina bermudezi* in possessing much inflated chambers, but does not develop a multiple aperture. Possibly specimens of this species of true *Hantkenina* may have been considered as transitional forms by Barnard.

Typical *Hantkenina* is found from the middle to upper Eocene, but *Cribrohantkenina* occurs only in the upper Eocene. We therefore consider these two as distinct genera on the basis of different apertural characters and different geologic ranges, although *Cribrohantkenina* undoubtedly developed from *Hantkenina*.

However, the subgenera *Aragonella* Thalmann, *Applinella* Thalmann, and *Hantkeninella* Bronnimann are much less distinctive, for a single species may show considerable variation in the chamber shape, and in the length of the spines and their apparent relative position. *Applinella* was defined as differing from typical *Hantkenina* in having the spines at the anterior portion of the chambers, whereas those of *Hantkenina* were nearly sutural in position. A glance at the final chamber of each species shows that the spines are in almost exactly similar positions, at the dorsal angle of the chamber. The different appearance in earlier chambers depends entirely on the amount of overlap by the following chamber. When the wall of the final chamber is attached just at the spine base of the previous chamber, the spine appears sutural in position. When the wall of the final chamber is more restricted, the preceding spine appears to be on the anterior portion of the penultimate chamber. Also, the wall of the final chamber may partially or wholly envelop the spine of the preceding chamber, so that it may appear spineless, or the spine may even seem to be protruding from the posterior portion of the final chamber. This character varies considerably in a species and may show some variation even on a single specimen. On the specimens we have of *H. alabamensis* (topotype), *H. alabamensis primitiva* (holotype), and *H.* (*Applinella*) *dumblei* (lectotype), the early chambers show the spines on the anterior portion of the chambers and not touching the following sutures, whereas the later chambers show a stronger overlap and the spines "appear" sutural. The final chamber is broken from the lectotype of *H. dumblei*, but the remnants of this final chamber show an attachment partially enveloping the base of the spine of the penultimate chamber. Therefore, the basis for separation of *Applinella* seems to be too variable in all these "subgenera" to be of value, and we consider *Applinella* a synonym of *Hantkenina*.

Hantkeninella was separated, as including only *H. alabamensis* var. *primitiva*, whose early chambers lack spines. Bronnimann (1950a, p. 417), in describing the subgenus, stated, "At present it is the only known *Hantkenina* with a spineless early stage and, therefore, it cannot be referred to any of the existing subgenera."

The development of spines is not an invariable character in this group, however. We have large suites of *H. alabamensis* including many specimens with nonspinose early chambers. We also have some with early chambers bearing spines and an occasional adult chamber lacking any spine. Rare specimens also occur with two or even three spines on a single chamber, both in *H. alabamensis* and in other species. Some specimens which are typical *H. brevispina* in all other characters lack spines on early chambers. In general, the young forms of all species show shorter and less well developed spines and, because of the amount of variation in this feature, we do not consider their absence on early chambers to be a diagnostic generic character. Therefore, *Hantkeninella* is considered synonymous with *Hantkenina*.

Hantkenina differs from *Schackoina* Thalmann in being planispiral, and in having a tripartite aperture, with an elongate slit extending up the apertural face, whereas *Schackoina* has a very low arched aperture.

Cribrohantkenina Thalmann differs in having multiple areal apertures instead of a triradial, interiomarginal equatorial aperture bordered by lateral flanges.

Types and Occurrence: Figured hypotype of *Hantkenina alabamensis* Cushman (USNM P4791) from the Pachuta formation, Jackson Eocene, Cushman's "Cocoa sand," 1 mile southwest of the old Cocoa Post Office, Choctaw County, Alabama. Collected by C. G. Lalicker. Figured hypotype of *H. alabamensis* Cushman (USNM P4786) from the Pachuta formation, 2.2 miles south of Melvin, Choctaw County, Alabama.

Holotype of *Hantkenina alabamensis primitiva* Cushman and Jarvis (Cushman Coll. 10067) from the Eocene Mount Moriah beds, from bed of yellow sandy clay directly underlying orbitoidal limestone of Vistabella quarry, Trinidad, B. W. I. Collected by P. W. Jarvis.

Lectotype of *Hantkenina dumblei* Weinzierl and Applin (Cushman Coll. No. 12204) and figured paratype (USNM P4790) from the Eocene Yegua formation, Rio Bravo Oil Co., Deussen B 1, 4010 feet, South Liberty Dome, Liberty County, Texas.

Lectotype of *Hantkenina mexicana* var. *aragonesis* Nuttall (Cushman Coll. 59476) from the Eocene Aragon formation, 2600 meters N. 73° E. of El Tule, México, and figured paratype (Cushman Coll. No. 59477) from the Aragon formation, 1200 meters N. 48° W. of La Antigua Crossing, México.

Range: Eocene.

Genus Cribrohantkenina Thalmann, 1942

Plate 2, Figures 9a–11b

Cribrohantkenina Thalmann, Amer. Journ. Sci., vol. 240, pp 812, 815, 819, 1942.

Type species: *Hantkenina* (*Cribrohantkenina*) *bermudezi* Thalmann, 1942. Fixed by original designation.

Test free, planispiral, biumbilicate; chambers subglobular, with the prominent peripheral spine at the forward margin of each chamber, succeeding chambers are attached near the base of the spines and may partially or completely envelop the spine of the preceding chamber; sutures distinct, depressed, radial; wall calcareous, perforate, surface smooth, finely punctate, or finely spinose; primary aperture interiomarginal, equatorial, secondary multiple areal aperture consisting of small rounded or elongate openings above the primary interiomarginal aperture, in well developed specimens the terminal portion of the chamber may form a protruding "poreplate," which lacks fine perforations in the area between the apertural pores, and may cover the primary interiomarginal aperture and attach to the peripheral margin of the previous whorl, the primary interiomarginal aperture and secondary areal apertures commonly bordered by distinct and protruding lips, and the multiple secondary openings may rarely be filled with a later-formed shell growth.

Remarks: *Cribrohantkenina* differs from *Hantkenina* Cushman in having the secondary multiple areal aperture in the region between the final spine and the primary interiomarginal aperture.

Sporohantkenina was defined by Bermudez (1937, p. 151) as a subgenus of *Hantkenina*, with *Hantkenina brevispina* Cushman, 1925, cited as type species. Thalmann in 1942 stated that the type species was a true *Hantkenina*, making *Sporohantkenina* a synonym of *Hantkenina*, s. s. He therefore proposed the name *Cribrohantkenina* for the species with a multiple aperture, and cited as type species *Cribrohantkenina bermudezi* Thalmann, new name for *Hantkenina brevispina* Bermudez, 1937, not *Hantkenina brevispina* Cushman, 1925. Later authors followed Thalmann (Cushman, 1948, p. 329; Glaessner, 1948, p. 149; Sigal, 1952a, p. 236, although he incorrectly indicated the illustrated species as *Cribrohantkenina brevispina* (Cushman); Le Calvez, 1953, p. 251; and Barnard 1954, p. 384) in recognizing the validity of *Cribrohantkenina*. However, Bermudez (1952, p. 109) again used the name *Sporohantkenina*, this time citing as type species " '*Hantkenina* (*Sporohantkenina*) *brevispina* Cushman,' Bermudez (not *Hantkenina brevispina* Cushman 1925), 1937," and added that the species was renamed by Thalmann as *Hantkenina* (*Cribrohantkenina*) *bermudezi* Thalmann, but probably was conspecific with *Hantkenina danvillensis* Howe and Wallace, 1934.

Bermudez cited certain Rules of Nomenclature to substantiate the validity of his generic name, namely Art. 30,I, and Opinion 65. These state in part (Art. 30,Ia): "When in the original publication of a genus, one of the species is definitely designated as type, this species shall be accepted as type regardless of any other consideration"; and (Art. 30,Ic) "A genus proposed with a single original species takes that species as its type." Opinion 65 states: "If an author designates a certain species as genotype, it is to be assumed that his determination of the species is correct; if a case presents itself in which it appears that an author has based his genus upon certain definite specimens, rather than upon a species, it would be well to submit the case, with full details, to the Commission."

Bermudez then quoted a personal communication from Doctor de Rivero, of Venezuela, who stated that she believed the original publication to indicate the Cuban specimens as the type, and therefore would uphold *Sporohantkenina*. However, in the original publication Bermudez stated that he had been given specimens of *H. brevispina* by Cushman, from the Méxican Eocene, and that he had a "good collection of specimens of *Hantkenina brevispina* Cushman" from Mexico, from the R. Wright Barker collection, given to him by Mrs. Dorothy K. Palmer. He then stated that in a collection of Cuban Eocene material, also obtained from Mrs. Palmer, were "abundantes ejemplares de *Hantkenina brevispina* Cushman." His description was therefore not based solely on the Cuban specimens. His discussion of the aperture was followed by the statement (translation), "The apertural character described above is very constant and of use in determining the species, as it has been observed only in *Hantkenina brevispina* . . ."; he therefore proposed the new subgenus. Bermudez thus definitely cited *Hantkenina brevispina* Cushman as type in the original publication with no question as to the identification of the Cuban specimens, and according to Art. 30, Ic, that was not only original designation, but also designation by monotypy.

The Copenhagen decisions on Zoological Nomenclature clarify some of the earlier rules, and a pertinent quotation is here given concerning Art. 30(c). In these decisions (1953, p. 70) it was stated that a genus would be considered as published "with only one included species . . . where more than one nominal species is so cited by the author of the generic name, but only one of these nominal species possesses a specific name validly published with an indication . . ." Thus, *Hantkenina brevispina* Cushman would be considered as designated by monotypy as it was the only valid specific name cited, even if two species were erroneously included, as no other named species was available.

The only possibility of a new type being later designated would arise in a case where the type species had been definitely cited in the original publication as not conspecific with Cushman's species. This possible recourse was stated in the above-cited Copenhagen decisions (p. 68) to be limited to cases ". . . where an author . . . designates as the type species a nominal species previously established by some author, and in doing so, makes it clear that he is applying that specific name, not to the species to which that name was applied by its original author, but to some species to which that name had been applied by some later author." This was the case in the erection of the name *Cribrohantkenina* by Thalmann, who definitely stated that Bermudez's specimens were the type for the proposed new generic and specific names, and that these were not conspecific with Cushman's original types. It was not the case in the original publication of Bermudez, as there was no question, stated or implied, as to the belief of the author in the validity of the specific determination. On the contrary, the references to the many specimens of true *H. brevispina* available to him substantiate the assumption that he considered the Cuban specimens correctly identified, and the type species to be Cushman's species. Thus, *Hantkenina brevispina* Cushman is the type species of *Sporohantkenina* by original designation and monotypy, and Thalmann was correct in suppressing the generic name as a synonym of *Hantkenina*, s. s.

Although originally described as a subgenus of *Hantkenina*, *Cribrohantkenina* was later elevated to generic rank (Cushman, 1948, p. 328). Barnard (1954, p. 384) showed the ontogenetic development of the aperture in *Cribrohantkenina*, although he considered it gradational with *Hantkenina*. It seems probable that he was dealing with more than one species, however, as in the many large suites of specimens we have studied, there seems to be a sharp boundary between the two. We consider both as distinct genera.

Types and occurrence: Figured hypotypes (USNM P4784a-c) and unfigured hypotypes (USNM P4785) of *Cribrohantkenina bermudezi* Thalmann from the Jackson Eocene, Pachuta formation, Cushman's "Cocoa sand," 2.2 miles south of Melvin, Choctaw County, Aabama.

Range: Upper Eocene.

Hastigerininae Bolli, Loeblich, and Tappan, new subfamily

Type genus: *Hastigerina* Thomson, 1876.

Coiling of test planispiral; chambers spherical to clavate; primary aperture equatorial, no secondary apertures present.

Range: Eocene to Recent.

Genus Hastigerina Thomson, 1876

Plate 3, Figures 1–4b

Hastigerina Thomson, Proc. Roy. Soc. London, vol. 24, p. 534, 1876.

Globigerinella Cushman, Contr. Cushman Lab. Foram. Res., vol. 3, p. 87, 1927. (Type species: *Globigerina aequilateralis* Brady, 1879. Fixed by original designation and monotypy.)

Type species: *Hastigerina murrayi* Thomson, 1876. Fixed by monotypy.

Test free, early stage may be slightly trochospiral, the adult planispiral, ranging from involute to loosely coiled, biumbilicate, periphery broadly rounded; chambers spherical to ovate; sutures deeply depressed, radial; wall finely to coarsely perforate, radial in structure, surface smooth, hispid, or spinose; aperture interiomarginal, a broad equatorial arch.

Remarks: Brady described the type species of the genus as *Hastigerina pelagica* (d'Orbigny) [=*Nonionina pelagica* d'Orbigny, 1839], placing *Hastigerina murrayi* Thomson in synonymy. D'Orbigny's original illustrations are similar, but no mention is made of an aperture, nor is one shown on the drawing. Furthermore, d'Orbigny's figures are of a specimen about one-third the size of *H. murrayi*. As the aperture is so large and characteristic in *H. murrayi*, we consider the two to be distinct and the valid name for the type species to be *Hastigerina murrayi* Thomson, 1876.

The great similarity of *Hastigerina* and *Globigerinella* Cushman is evident, and was in fact noted by Brady (1884, p. 614), who stated that the only species with which *Hastigerina pelagica* (=*H. murrayi*) "is likely to be confounded is *Globigerina aequilateralis*," and it later became the type species of *Globigerinella*. He added that the latter was evolute. In the original description of *Globigerinella*, no comparisons were given by Cushman as to how the two genera could be differentiated. In later texts a discussion was given of the relative coarseness of spines but no statement as to how the two genera could otherwise be separated. The type of ornamentation is variable in planktonic genera, and the type species of both *Hastigerina* and *Globigerinella* range from nearly involute to somewhat evolute. This is therefore not regarded as a sufficient basis for generic separation and *Globigerinella* is considered a junior synonym of *Hastigerina*.

Mesozoic species referred to *Globigerinella* upon close examination will be seen to belong either to *Planomalina* Loeblich and Tappan, *Biglobigerinella* Lalicker, or to *Globigerinelloides* Cushman and ten Dam.

Types and occurrence: Figured hypotypes of *Hastigerina murrayi* Thomson are the specimens figured and described by Brady as *Hastigerina pelagica* (d'Orbigny). The dead shell here figured (BMNH ZF 1563) from dredging at 1,990 fathoms, *Challenger* Station 338, in the South Atlantic, lat. 21° 15′ S., long. 14° 02′ W. Hypotypes (BMNH ZF 1562) mounted in balsam, were living specimens taken by tow net of the *Challenger*, but the exact locality is not given. The side view of the balsam-mounted specimen is of the same figured by Brady, but the apertural view in balsam is of a different specimen on the same slide and not that figured by Brady in this orientation.

Original types of *Globigerinella aequilateralis* (Brady) in the British Museum (Natural History), London. Figured topotype (USNM P3918) and unfigured topotypes (USNM P3211) from the Recent at *Challenger* Station 224, lat. 7° 45′ N., long. 144° 20′ E., at 1,850 fathoms. Collected March 21, 1875.

Range: Middle Eocene to Recent.

Clavigerinella Bolli, Loeblich, and Tappan, new genus

Type species: *Clavigerinella akersi*, new species. (Derivation: *Claviger*, L., club-bearing + *ina* + *ella*, L. diminutives; gender, feminine.)

Test free, planispiral, biumbilicate, involute, radially lobulate in outline; chambers spherical in the early stages, later becoming radially elongate or clavate; sutures radial, depressed; wall calcareous, finely perforate, radial in structure, surface finely pitted; aperture interiomarginal, equatorial, an elongate slit extending up the apertural face, bordered laterally by wide flanges which narrow toward the upper extremity of the aperture, where they join to form a small lip.

Remarks: *Clavigerinella*, new genus, resembles *Hastigerinella* Cushman in having early globular chambers followed by later radial elongate and clavate chambers. It differs in being planispiral instead of trochospiral, and in having the distinctive equatorial aperture elongated in the plane of coiling and bordered laterally by flanges. The aperture is reminiscent of that in *Hantkenina aragonensis* Nuttall, but the present genus does not have tubulospines, and *Hantkenina* may only have radially elongate chambers which never become clavate.

Clavigerinella, new genus, differs from *Hastigerinoides* Bronnimann in having the distinctly elongate slitlike equatorial aperture and wide bordering flanges and in lacking, around the umbilical region, the secondary relict apertures which are the persistent lateral margins of the earlier equatorial primary apertures. As a rule, the chambers of *Hastigerinoides* are tapering and those of *Clavigerinella* are club-shaped.

Range: Middle to upper Eocene.

Clavigerinella akersi Bolli, Loeblich, and Tappan, new species

Plate 3, Figures 5a, b

Test free, planispiral, biumbilicate, involute, lobulate in outline; early chambers spherical, later chambers radial elongate and typically much inflated at the extremity, with four chambers in the final whorl; sutures radial, distinct and depressed; wall calcareous, distinctly perforate, surface finely pitted; aperture interiomarginal, equatorial, an elongate slit extending up the apertural face for about half the length of the final chamber, aperture bordered laterally by wide flanges which are flared at the base and become progressively narrower toward the upper extremity of the aperture, joining at the top to form a narrow lip, a short distance below the bulbous or clavate extreme of the chamber.

Greatest diameter of holotype 0.86 mm., greatest thickness 0.23 mm. Paratypes range from 0.49 to 0.73 mm. in greatest diameter.

Remarks: This species differs from *Hastigerinella eocanica* Nuttall var. *aragonensis* Nuttal from the Eocene of México, in having the terminally clavate chambers, with their nearly spherical inflations, and in having only four chambers per whorl. The Mexican species has narrower, more elongate cylindrical chambers and may have four or five chambers per whorl, but also belongs to the present genus.

The species is named in honor of W. H. Akers, paleontologist with The California Company, in recognition of his work on the planktonic Foraminifera of the Gulf Coast.

Types and occurrence: Holotype (USNM P4550) and unfigured paratypes (USNM P4551) from the Eocene Navet formation, equivalent in age to the Friendship Quarry marl and Dunmore Hill marl (middle Eocene) in Spring Branch of the Navet River, 1,100 feet south of the 12.5 milepost of the Brasso-Tamana Road, Central Range, Trinidad, B. W. I. Collected by Dr. Hans Kugler, sample K.8820.

Cassigerinellinae Bolli, Loeblich, and Tappan, new subfamily

Type genus: *Cassigerinella* Pokorný, 1955.

Coiling of test planispiral in the early stage, becoming enrolled biserial in the later stage; chambers spherical to ovate; primary aperture equatorial in neanic stage, extraumbilical and alternating in the adult.

Range: Oligocene to Miocene.

Genus Cassigerinella Pokorný, 1955

Plate 3, Figures 6a–c

Cassigerinella Pokorný, Věstník Ústředního Ústavu Geologického, vol. 30, p. 136, 1955.

Type species: *Cassigerinella boudecensis* Pokorný, 1955. Fixed by original designation.

Test free, robust, early portion planispiral and similar to *Hastigerina*, later with biserially arranged chambers continuing to spiral in the same plane, biumbilicate, periphery broadly rounded; chambers globular to ovate and only a few pairs arranged as in *Cassidulina* to each whorl of the test; sutures distinct, depressed, radial to curved; wall calcareous, perforate, radial in structure, surface smooth to pitted; aperture interiomarginal, an extraumbilical arch alternating in position from one side to the next in successive chambers.

Remarks: *Cassigerinella* differs from *Hastigerina* Thomson in having the adult spire composed of biserially arranged chambers. *Biglobigerinella* Lalicker is similar in early planispiral development but has only a single pair of "biserial" chambers, which are opposing, however, rather than alternating, and each of which has a distinct aperture. It differs from *Cassidulina* d'Orbigny in having a perforate radial wall structure rather than granular and in having an early planispiral stage.

Types and occurrence: Figured topotype (USNM P3389) and unfigured topotypes (USNM P3056) from the Middle Oligocene, Boudky near Velké Němčice, Moravia, Czechoslovakia. Collected by Dr. Vladimír Pokorný.

Range: Oligocene to Miocene.

Family Orbulinidae Schultze, 1854

Type genus: *Orbulina* d'Orbigny, 1839.

Test trochospirally or streptospirally coiled or globular; chambers spherical, ovate or clavate; wall calcareous, perforate, radial in structure; primary aperture umbilical or spiroumbilical, may have secondary sutural or areal apertures and may have bullae and accessory infralaminal apertures.

Subfamily Globigerininae Carpenter, 1862

Type genus: *Globigerina* d'Orbigny, 1826.

Coiling of test trochospiral to streptospiral; chambers spherical, ovate or clavate; primary aperture umbilical or spiroumbilical, may have secondary sutural apertures.

Range: Cretaceous to Recent.

Genus Globigerina d'Orbigny, 1826

Plate 4, Figures 1a–c

Globigerina d'Orbigny, Ann. Sci. Nat., ser. 1, vol. 7, p. 277, 1826.

Type species: *Globigerina bulloides* d'Orbigny, 1826. Fixed by subsequent designation of Parker, Jones and Brady (1865, p. 36).

Test free, trochospiral, chambers spherical to ovate; sutures depressed, radial; wall calcareous, perforate, radial in structure, surface may be smooth, pitted, cancellated, hispid or spinose; aperture interiomarginal, umbilical, with a tendency in some species to extend to a slightly extraumbilical position, and previous apertures remaining open into the umbilicus.

Remarks: Formerly considered a more inclusive genus, *Globigerina* is now restricted to include only those trochospiral species with a single large open umbilical aperture.

In *Globigerina* the aperture is interiomarginal and primarily umbilical, leading from each chamber into the open umbilicus, and the chambers are always globular to subglobular. *Globorotalia* has an interiomarginal, extraumbilical-umbilical aperture, and the chambers vary from ovate or subhemispherical to strongly compressed or angular, commonly have a peripheral keel but rarely are truly spherical. *Praeglobotruncana* has an extraumbilical-umbilical aperture like that of *Globorotalia*, but commonly with spherical or only slightly compressed chambers.

All classifications are somewhat artificial and there are some species with globular chambers whose apertural position is transitional, so that in some instances it may be somewhat difficult to decide whether such a species should be placed in *Globigerina* or *Globorotalia*.

Types and occurrence: This genus, like the majority of planktonic forms, has a wide geographic occurrence. The hypotype of *G. bulloides* d'Orbigny here figured (USNM P3917) is from Recent beach sand at Marina di Ravenna (Porto Corsini), Italy. Collected by H. T. and A. R. Loeblich, Jr., March 15, 1954. The original type locality of d'Orbigny was at Rimini, approximately 60 kilometers farther south on the Italian coast.

Range: Cretaceous to Recent.

There is a continuous geologic record of *Globigerina* from the Paleocene to Recent and, in addition, species are found from the Hauterivian to Cenomanian in the Lower and Middle Cretaceous which appear to be morphologically identical. The gap in the geologic record from the Cenomanian to Paleocene strongly suggests that this genus as here recognized is polyphyletic, and the Tertiary species are not direct descendants from those of the Lower Cretaceous. The absence of any distinguishing morphologic characters prevents their separation, with the material and methods thus far available, into two nominal genera.

Genus Globoquadrina Finlay, 1947

Plate 5, Figures 4a–6

Globoquadrina Finlay, New Zealand Journ. Sci. Tech., vol. 28, No. 5 (sec. B), p. 290, 1947.

Type species: *Globorotalia dehiscens* Chapman, Parr and Collins, 1934. Fixed by original designation.

Test free, trochospiral, umbilicate, periphery rounded to truncate; chambers spherical to subangular truncate; wall calcareous, perforate, radial in structure, surface pitted to hispid; aperture interiomarginal, umbilical, covered above by an apertural flap which may vary from a narrow rim to an elongate toothlike projection, and in openly umbilicate forms earlier apertures remain open into the umbilicus.

Remarks: *Globoquadrina* differs from *Globigerina* d'Orbigny in having apertural flaps covering each aperture. It differs from *Globorotalia* in the aperture being umbilical instead of extraumbilical-umbilical in position.

Types and occurrence: Figured hypotype (USNM P3926) and unfigured hypotype (USNM P3927) of *Globoquadrina dehiscens* (Chapman, Parr, and Collins) from the Miocene (Balcombian) at Balcombe Bay, Victoria, Australia. Collected by A. C. Collins.

Unfigured hypotypes (Cushman Coll. 14240) from the Balcombian at Grices Creek, Victoria, Australia; (Cushman Coll. 24844) from the Miocene at Western Beach, Geelong, Victoria, Australia; and (Cushman Coll. 24837) from the Lower Miocene, lower beds, Muddy Creek, Victoria, Australia. All from W. J. Parr.

Holotype of *Globoquadrina altispira* (Cushman and Jarvis) (Cushman Coll. 22482) from the Miocene Bowden marl at milestone 71 east of Port Antonio, Jamaica, B. W. I.

Figured specimen of *Globoquadrina* sp. (USNM P4575) from the *Globorotalia mayeri* zone of the Miocene Lengua formation, on Cunjal road, between Barackpore and Princes Town, Trinidad, B. W. I.

RANGE: Upper Eocene to Miocene.

Genus Hastigerinella Cushman, 1927

PLATE 5, FIGURES 1–3b

Hastigerinella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, p. 87, 1927.

TYPE SPECIES: *Hastigerina digitata* Rhumbler, 1911 [=*Hastigerinella rhumbleri* Galloway, 1933]. Fixed by original designation and monotypy.

Test free, trochospiral, early portion with globular chambers, later chambers radially elongate, clavate or cylindrical; sutures distinct, depressed, radial; wall calcareous, perforate, radial in structure, with elongate spines which may be concentrated at the outer ends of the chambers, but are normally broken away in fossil or dead shells; aperture interiomarginal, extraumbilical-umbilical, a broad arch which becomes more extensive with age, extending to the periphery or even becoming spiroumbilical.

REMARKS: *Hastigerinella* differs from *Hastigerina* in being trochospiral instead of planispiral, and in having elongate chambers. It differs from *Hastigerinoides* Bronnimann in being distinctly trochospiral rather than planispiral.

Cushman, in describing *Hastigerinella* (1927, p. 87), cited as type species "*Hastigerina digitata* Rhumbler, Foram. Plankton Exped., Part 1, 1911, pl. 37, fig. 9a,b." The *digitata* of Rhumbler, 1911, is not conspecific with *Globigerina digitata* Brady, 1879, which is another species of *Hastigerinella*. This led Galloway (1933, p. 333) to cite as type *Hastigerinella rhumbleri* n. sp. This confusion primarily results from Rhumbler's failure to give any descriptions for his plates in the "Plankton-Expedition" volume cited above. However, Ellis and Messina (1949, p. 40) published the plate explanations of Rhumbler's "Plankton-Expedition" that they had obtained as a manuscript from Dr. Otto Wetzel. The copy furnished by Dr. Wetzel was from the manuscript preserved in the library of the University of Göttingen, Germany. On the plate explanation for plate 37, figs. 9a,b were stated to be *Hastigerina digitata* (Brady) variante *digitifera*. This "variante" is thus the use of a new name, but it is invalid, according to the Rules of Nomenclature (Art. 25c), as no description was given. It must be assumed that Cushman considered the combination *Hastigerina digitata* as used by Rhumbler (1911, pp. 202, 220) as being a new combination and not referring to *Globigerina digitata* Brady, 1879, for nowhere did Rhumbler (1911) use the name Brady in combination with *Hastigerina digitata*. The type thus should be cited as *Hastigerina digitata* Rhumbler, 1911, but this is a homonyn of *H. digitata* (Brady), 1879. Galloway in reality only renamed this homonyn and did not describe a new species as he stated, hence the name *Hastigerinella rhumbleri* Galloway, 1933, is the valid name for the species.

TYPES AND OCCURRENCE: The original specimens figured by Rhumbler were from the Atlantic Ocean in 2,000 meters. Figured hypotype of *Hastigerinella digitata* (Brady) (USNM P3037) is from *Challenger* Station 120, lat. 8° 37′ S., long. 34° 28′ W., at 675 fathoms.

RANGE: Miocene to Recent.

Genus Globigerinoides Cushman, 1927

PLATE 4, FIGURES 2a–c

Globigerinoides CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, p. 87, 1927.

TYPE SPECIES: *Globigerina rubra* d'Orbigny, 1839. Fixed by original designation and monotypy.

Test free, trochospiral; chambers globular to ovate; sutures depressed, radial; wall calcareous, perforate, radial in structure, surface smooth, hispid or spinose; primary aperture interiomarginal, umbilical, with previous apertures remaining open into the umbilicus, smaller secondary sutural apertures on the spiral side, one or more per chamber, often confined to the last few chambers.

REMARKS: The type species has a distinctive coloration, being rose-colored in the early portion, later chambers progressively lighter, and final chamber nearly white. D'Orbigny originally described the species as having two supplementary apertures on the final chamber and one on the preceding, but added that the number was variable in other specimens. In the specimen here figured there are two secondary apertures on the spiral side of each chamber of the final whorl, although the specimen must be rotated to see all of them.

Globigerinoides differs from *Globigerina* d'Orbigny in possessing the secondary sutural apertures on the spiral side.

TYPES AND OCCURRENCE: The original types of *Globigerina rubra* d'Orbigny are in the Musuem National d'Histoire Naturelle, Paris. Figured hypotype of *Globigerinoides rubra* (d'Orbigny) (USNM P3916) from the Recent, *Albatross* Station H 47, lat. 17° 46′ 30″ N., long. 65° 10′ 25″ W., at 1,482 fathoms.

RANGE: Paleocene to Recent.

Genus Sphaeroidinella Cushman, 1927

PLATE 6, FIGURES 1–5

Sphaeroidinella CUSHMAN, Contr. Cushman Lab. Foram. Res., vol. 3, p. 90, 1927.

TYPE SPECIES: *Sphaeroidina dehiscens* Parker and Jones, 1865. Fixed by original designation and monotypy.

Test free, elongate ovate, early portion trochospiral, the two or three much-embracing chambers of the final whorl enveloping the early whorl, each with marginal flanges extending out toward the opposing chambers and partially obscuring the arched apertures; sutures depressed, radial or curved; wall calcareous, perforate, radial in structure, in the young stage the pores are extremely large and closely arranged, giving an almost latticelike appearance, the area between pores raised and cancellated, in the later chambers a somewhat irregularly fimbriate or scalloped flange, of clear shell material and relatively poreless, is formed around the chamber near its base and tends to coalesce laterally and become much produced, the exterior surface of the final chambers is smoother and glassy in appearance, rather than hispid, and appears to be due to an external secondary deposit; primary aperture in the young stage as in *Globigerina*, interiomarginal umbilical, in the adult this is covered by the embracing final chamber, and there may be one or more sutural secondary apertures on opposite sides of the final chamber, but these may be partially obscured by the overhanging chamber flanges which parallel the sutures, the chambers may be distinctly separated with a wide open area between the flanges of opposing chambers, and there may be small arched bullae crossing the sutural slit, and partially covering the apertural regions, the walls of the bullae more smoothly finished than that of the chamber, with finer pores although of similar spacing.

Remarks: *Sphaeroidinella* differs from *Globigerina* d'Orbigny in having embracing later chambers which cover the primary umbilical aperture, the chambers developing flanges paralleling the sutures and partially obscuring the secondary apertures. There may also be more than one secondary sutural aperture in the final stage, and occasional specimens develop small bullae over the sutural apertures. It resembles *Globigerinatheka* Bronnimann in the enveloping final chamber, sutural secondary apertures and bullae, but differs in having the typical chamber flanges in the adult and the final involute coiling obscuring the early coil. The bullae, when present, are relatively small arches and do not completely cover the secondary apertures.

Types and occurrence: Lectotype of *Sphaeroidina dehiscens* Parker and Jones, 1865 (here designated) British Museum (Natural History) ZF 3580 and paratypes ZF 3579 from 1,080 fathoms, lat. 2° 20′ N., long. 28° 44′ W. Figured paratypes (from the type locality) (USNM P4224).

Figured hypotypes (USNM P4225) and unfigured hypotypes (USNM P4226) from *Challenger* Station 224, lat. 7° 45′ N., long. 144° 20′ E., at 1,850 fathoms.

Range: Miocene to Recent.

Genus Pulleniatina Cushman, 1927

Plate 4, Figures 3a–5

Pulleniatina Cushman, Contr. Cushman Lab. Foram. Res., vol. 3, p. 90, 1927.

Type species: *Pullenia obliqueloculata* Parker and Jones, 1865. Fixed by original designation and monotypy.

Test free, globose, trochospiral to streptospiral, early portion as in *Globigerina*, with open umbilicus, later chambers completely enveloping the entire umbilical side of the previous trochospiral coil, including the previous open umbilicus, and thus may even appear involutely coiled; wall calcareous, perforate, radial in structure, later part comparatively thickened, surface distinctly hispid in the *Globigerina* stage, as can be seen in dissected tests, the surface in the adult smooth, although the portion of the earlier whorl just below the aperture may show the hispid surface; aperture interiomarginal, in the young a broad umbilical arch, as in *Globigerina*, in the adult a broad low extraumbilical arch at the base of the final enveloping chamber, bordered above by a thickened lip, but not directly opening into the earlier umbilicus, because of the streptospiral plan of growth.

Remarks: *Pulleniatina* resembles *Globigerina* d'Orbigny in the early development, but differs in the later streptospiral coiling and embracing final chamber and in the characteristic extraumbilical peripheral aperture.

Pulleniatina resembles *Globigerapsis*, new genus, in having the *Globigerina* stage followed by a more embracing final chamber, and in the change in coiling from trochospiral to streptospiral, but *Pulleniatina* has a single aperture, whereas *Globigerapsis* has in the final chamber multiple apertures which are against the sutures of the early coil.

Types and occurrence: Lectotype (here designated) of *Pullenia obliqueloculata* Parker and Jones, 1865 (the type species of *Pulleniatina*), British Museum (Natural History) No. ZF 3583, and figured paratype (USNM P4228) from Abrohlos Bank, at 260 fathoms, lat. 22° 54′ S., long. 40° 37′ W., in the South Atlantic.

Figured hypotypes (USNM P4229a, b) from *Challenger* Station 224, at 1,850 fathoms, lat. 7° 45′ N., long. 144° 20′ E., collected March 21, 1875.

Range: Pliocene to Recent.

Subfamily Orbulininae Schultze, 1854

Type genus: *Orbulina* d'Orbigny, 1839.

Coiling trochospiral to streptospiral, later stages enveloping or globular; chambers spherical to ovate; primary aperture not visible in adult, secondary apertures multiple and sutural or areal.

Range: Middle Eocene to Recent.

Globigerapsis Bolli, Loeblich, and Tappan, new genus

Plate 6, Figures 7a–c

Type species: *Globigerapsis kugleri* Bolli, Loeblich and Tappan, new species. (Derivation: *Globus*, L., a globe or ball + *gero*, L., to bear or carry + *apsis*, L., arch; gender, feminine.)

Test free, subglobular; early portion trochospiral with subglobular chambers, final chamber embracing and covering the umbilical region of the early coil; sutures depressed, radial to curved; wall calcareous, perforate, radial in structure, surface smooth to hispid or spinose, the spines broken from the later chambers during preservation, but remaining visible on the earlier chambers when unfilled specimens are dissected; primary aperture interiomarginal, umbilical in the young stage, covered in the adult by an enveloping final chamber, with two or more arched secondary apertures at the lower margin of the final chamber, at the contact with the sutures of the earlier whorl.

Remarks: *Globigerapsis*, new genus, differs from *Globigerinatheka* Bronnimann in lacking the small angular bullae covering the secondary apertures. It differs from *Globigerinoides* Cushman in the absence of an umbilical primary aperture in the adult. *Globigerapsis* does not show the multiple apertures on earlier chambers as does *Globigerinoides* and *Porticulasphaera*, new genus.

Bronnimann (1952a, p. 27, text-fig. 3d-f) included a single specimen of *Globigerapsis kugleri* with his *Globigerinatheka barri*, considering it to represent a stage prior to the development of the sutural bullae. Although the two genera may be closely related, they have different geologic ranges, the present genus beginning earlier.

Globigerinoides semiinvoluta Keijzer also belongs to the present genus and a hypotype (USNM P3937) from the Eocene Navet formation, Hospital Hill marl, *Globigerapsis semiinvoluta* zone type locality, San Fernando, Trinidad, B. W. I., is here figured for comparison.

Bermudez (1949), p. 279, pl. 21, fig. 44) described as *Globigerina mexicana* Cushman a specimen which actually belongs to the present genus, and seems closer to the species *Globigerapsis semiinvoluta* (Keijzer), although it is perhaps a distinct species.

Range: Middle to upper Eocene.

Globigerapsis kugleri Bolli, Loeblich, and Tappan, new species

Plate 6, Figures 6a–c

Test free, subglobular, early portion trochospiral with globular chambers increasing rapidly in size as added, about four to each whorl, final chamber considerably larger and somewhat embracing, covering the umbilical region of the early coil; sutures deeply depressed, commonly almost incised, radial to curved; wall calcareous, coarsely perforate, surface originally finely spinose, but surface spines broken in fossilization, although those of earlier chambers remain visible in dissected specimens, or may be seen through the apertural openings of the final chamber; aperture in the early stage interiomarginal, umbilical, but this is covered in the adult by the final embracing chamber, which has two to four arched sutural secondary apertures, each bordered by a slight lip, at the basal margin of the final chamber.

Greatest diameter of holotype 0.44 mm., greatest thickness 0.47 mm. Paratypes range from 0.36 to 0.47 mm. in greatest diameter.

Remarks: *Globigerapsis kugleri*, new species, differs from *Globigerapsis semiinvoluta* (Keijzer) in having more inflated and nearly globular chambers, more deeply incised sutures, a somewhat less embracing final chamber and lower and less arched secondary apertural openings. It is also similar in appearance to *Globigerinatheka barri* Bronnimann but may have a less embracing final chamber, and always lacks the small bullae which cover the secondary sutural apertures of *Globigerinatheka*.

The specific name is in honor of Dr. H. G. Kugler, in recognition of his work on the geology of Trinidad, B. W. I.

Types and occurrence: Holotype (USNM No. P4220), unfigured paratypes (USNM P4221, 4222, and 4827) from the Eocene Navet formation, Penitence Hill marl, *Globigerinatheka barri* zone, from a block in the Oligocene Nariva formation, Pointe-a-Pierre, Trinidad, B. W. I.

Porticulasphaera Bolli, Loeblich, and Tappan, new genus

Type species: *Globigerina mexicana* Cushman, 1925. (Derivation: *Porticula*, L., diminutive of *porticus*, an arcade, series of arches+*sphaera*, L., ball; gender, feminine.)

Test free, subglobular, early portion trochospiral, final chamber much inflated to almost spherical, and strongly enveloping, covering the umbilical region of the early coil; sutures depressed, radial to curved; wall calcareous, comparatively thick, coarsely perforate, radial in structure, surface with numerous fine elongate spines, broken from the exterior, but those of the early portion may be preserved in the interior and visible in dissected specimens; primary aperture in the early portion interiomarginal, umbilical, with secondary sutural openings on the spiral side, as in *Globigerinoides*, the umbilical aperture covered by the final enveloping chamber of the adult, which has smaller sutural secondary apertures around its lower margin; these, together with the secondary sutural apertures on the spiral side, remain uncovered.

Remarks: *Porticulasphaera*, new genus, resembles *Orbulina* d'Orbigny in having a strongly embracing final chamber, although less inflated. In *Porticulasphaera* the early coil always remains visible, and there are no areal secondary apertures as in *Orbulina*.

It resembles *Globigerinoides* Cushman in having the multiple sutural secondary apertures in addition to the large interiomarginal umbilical primary aperture in the early portion, but differs in having the embracing final chamber obscuring the primary umbilical aperture, the adult possessing only the small sutural secondary openings.

Porticulasphaera, new genus, differs from *Globigerapsis*, new genus, in having the *Globigerinoides*-type of secondary apertures on the spiral side in the early coil.

Range: Middle Eocene.

Porticulasphaera mexicana (Cushman), emended

Plate 6, Figures 8–9b

Globigerina mexicana Cushman, Contr. Cushman Lab. Foram. Res., vol. 1, No. 3, p. 6, pl. 1, figs. 8a-b, 1925.

Test free, subglobular, of medium size, early portion in a low trochospiral coil with five inflated chambers per whorl, final chamber hemispherical, much inflated and strongly embracing and enveloping the umbilical region of the early coil, larger in size than the entire previous portion of the test; sutures generally distinct and depressed; wall calcareous, coarsely perforate, radial in structure, thin and delicate in the early portion, but wall of final embracing chamber very thick, with a secondary layer of comparable thickness covering the remaining exposed portion of the earlier whorls and somewhat obscuring the chamber contacts but leaving open the sutural apertures, surface finely spinose, the elongate delicate spines visible on earlier chambers in the interior of dissected specimens, but broken from the exterior of the fossil shells; primary aperture in the early portion interiomarginal, umbilical, an extremely large opening, with smaller arched secondary sutural openings on the spiral side as in *Globigerinoides*, the primary aperture of the early portion covered by the final embracing chamber, which has only the numerous small arched, sutural secondary apertures (as many as 25) completely encircling its basal margin.

Greatest diameter of figured hypotype 0.65 mm. Other specimens range from 0.42 to 0.83 mm. in greatest diameter.

Remarks: *Porticulasphaera mexicana* was originally described from the upper Eocene Tantoyuca formation, Vera Cruz, México. It was recorded as *Globigerinoides mexicana* (Cushman) by Beckmann (1953, p. 393, pl. 25, figs. 15–19) from the Oceanic formation of Barbados.

Types and occurrence: Holotype (Cushman Coll. 4334) from the upper Eocene Tantoyuca formation, Palacho Hacienda, south of Panuco-Tampico railroad, State of Vera Cruz, Mexico. Figured hypotype (USNM P3901), figured dissected hypotype (USNM P3902), and unfigured hypotypes (USNM P3903 and P3906) from the Eocene Navet formation, Penitence Hill marl, *Globigerinatheka barri* zone, in a block in the Oligocene Nariva formation, Pointe-a-Pierre, Trinidad, B. W. I.

Unfigured hypotypes (USNM P4855) from the *Globigerina* facies of the Middle Eocene Guayabal formation ("Lower Chapapote") in Tierra Amarilla Well No. 25, at 1,200 feet, Vera Cruz, México. From R. Wright Barker.

Unfigured hypotypes (USNM P3904) from the Navet formation (Penitence Hill marl), Town Hall site, San Fernando, Trinidad, B. W. I.

Unfigured hypotypes (USNM P3905) from the Oceanic formation (Lower Mount Hillaby member), Mount Hillaby section, Barbados, B. W. I. Collected by J. P. Beckmann.

Genus Candeina d'Orbigny, 1839

Plate 6, Figures 10a–11

Candeina d'Orbigny, Foraminifères, *in* de la Sagra, Histoire physique, politique et naturelle de l'Île de Cuba, p. 107, 1839.

Type species: *Candeina nitida* d'Orbigny, 1839. Fixed by monotypy.

Test free, trochospiral, relatively high spired; chambers globular to hemispherical; sutures depressed, radial to curved; wall calcareous, finely perforate, radial in structure, surface smooth; primary aperture in the very early stage interiomarginal, umbilical, later in development smaller secondary sutural apertures occur on each side of the primary aperture; in adult tests there is no primary opening and the small rounded sutural secondary apertures almost completely surround the later chambers.

Remarks: *Candeina* differs from *Globigerina* d'Orbigny in lacking the umbilical primary aperture in the adult, and in having the numerous rounded sutural secondary apertures. It differs from *Globigerinoides* Cushman in lacking the umbilical primary aperture and in having numerous small sutural secondary openings on both spiral and umbilical sides of the test, instead of having a relatively few larger secondary sutural apertures on the spiral side only.

Candeina passes through a *Globigerina* stage and a *Globigerinoides* stage in its ontogenetic development, as can be seen by a dissection of the test.

Hofker (1954, p. 151) stated that *Candeina* has a reduced toothplate, but the specimens we dissected show nothing that could be so construed. The upper border of the aperture is merely slightly thickened, as is often true of *Globigerina*.

Types and occurrence: Figured hypotype (USNM P3924) of *Candenia nitida* d'Orbigny from *Albatross* Station 2660, lat. 28°40′00″ N., long. 78°46′00″ W., depth 504 fathoms. Figured hypotype of dissected specimen (USNM P3923) of *C. nitida* from *Albatross* Station D.2754, lat. 11°40′00″ N., long. 58°33′00″ W., at a depth of 880 fathoms.

Range: Miocene to Recent.

Genus Orbulina d'Orbigny, 1839

Plate 7, Figures 1–5

Orbulina d'Orbigny, Foraminifères *in* de la Sagra, Histoire physique, politique et naturelle de l'Île de Cuba, p. 2, 1839.

Candorbulina Jedlitschka, Verh. Naturf. Ver. Brünn, vol. 65, p. 20, 1934. (Type species: *Candorbulina universa* Jedlitschka, 1934. Fixed by monotypy.)

Biorbulina Blow, Micropaleontology, vol. 2, No. 1, p. 69, 1956. (Type species: *Globigerina bilobata* d'Orbigny, 1846. Fixed by original desgination and monotypy.)

Type species: *Orbulina universa* d'Orbigny, 1839. Fixed by monotypy.

Test free, generally spherical and composed of a single chamber, rarely 2- or 3-chambered, or specimens may occur with early chambers arranged trochospirally, in the adult the globigerine coil may remain visible at one side, or may be completely enveloped by the final spherical chamber, or the test may consist of a number of completely enveloping and concentric globular chambers; wall calcareous, perforate, radial in structure; primary aperture interiomarginal, umbilical in the early globigerine stage, where this is present, but areal in the adult, with numerous small openings which may be scattered over one side or over much of the test, small sutural secondary openings commonly found around the early globigerine chambers of specimens where these are visible at the surface.

Remarks: As shown by Bronnimann (1951a, p. 133) there is a variation from the completely spherical single chamber to the more rare 2- or even 3-chambered forms, and to those forms with a globigerine coil either completely or partially enclosed by the globular end chamber. *Biorbulina* and *Candorbulina* are therefore synonyms of *Orbulina*. Unilocular, bilocular and trilocular forms are here illustrated, as well as those of "*Candorbulina*" type with globigerine coil visible at one side.

Types and occurrence: Figured hypotype of *Orbulina universa* d'Orbigny (USNM P3910) from *Albatross* Station D.2377, lat. 29°07′30″ N., long. 88°08′00″ W., in gray mud at 210 fathoms; 3-chambered hypotype (USNM P3911) from *Albatross* Station D.2042, lat. 39°33′00″ N., long. 68°26′45″ W., depth 1,555 fathoms; 2-chambered hypotype (USNM P3909) such as was named *Biorbulina*, from *Albatross* Station D.2660, lat. 28°40′00″ N., long. 78°46′00″ W., depth 504 fathoms; hypotype of *Orbulina universa* d'Orbigny (USNM P3908) showing "*Candorbulina*" development of test from the Miocene Choctawhatchee formation (lower *Arca* zone) near head of Vaughan Creek, Sec. 27, T.2 N., R. 19 W., Walton County, Florida; and figured hypotype (USNM P3907) showing "*Candorbulina* stage of development from the Miocene, Baden near Vienna, Austria.

Range: Miocene to Recent.

Catapsydracinae Bolli, Loeblich, and Tappan, new subfamily

Type genus: *Catapsydrax*, new genus.

Test trochospirally coiled to enveloping; chambers spherical to ovate; primary aperture umbilical, may have secondary sutural or areal apertures, apertures in the adult covered by bullae and with infralaminal accessory apertures.

Range: Middle Eocene to Recent.

Catapsydrax Bolli, Loeblich, and Tappan, new genus

Plate 7, Figures 6a–8c

Type species: *Globigerina dissimilis* Cushman and Bermudez, 1937. (Derivation: *Kata*, Gr., down, below + *psydrax*, Gr., blister; gender, masculine.)

Test free, trochospiral; chambers spherical to ovate; sutures depressed, radial; wall calcareous, perforate, radial in structure, surface smooth or pitted; primary aperture interiomarginal, umbilical, in the final stage covered by a single umbilical bulla, with one or more accessory infralaminal apertures.

Remarks: *Catapsydrax*, new genus, differs from *Globigerina* d'Orbigny in the presence of the umbilical bulla covering the primary aperture, and in having the accessory infralaminal apertures.

It differs from *Globigerinita* Bronnimann in having a small umbilical bulla with relatively few infralaminal accessory apertures which are sutural in position. In *Globigerinita* the bulla spreads along the sutures and the accessory apertures occur all along its margins.

Catapsydrax resembles *Globigerinatheka* Bronnimann in having the bulla but differs in having a single umbilical one, rather than more than one, situated in sutural positions.

Types and occurrence: In addition to the type species, *C. dissimilis*, three new Tertiary species of this genus are here described.

Catapsydrax dissimilis was originally described as *Globigerina dissimilis* Cushman and Bermudez. The holotype (Cushman Coll. 23430) and paratypes (Cushman Coll. 23429) are from the Eocene, 1 kilometer north of Arroyo Arenas, on road to Jaimanitas (water well), Havana Province, Cuba. Collected by P. J. Bermudez.

Figured hypotypes (USNM P4218a, b) are from the Oligocene Cipero formation, *Globigerina ciperoensis* zone, Cipero Coast section, Trinidad, B. W. I. Collected by H. M. Bolli.

Range: Upper Eocene to Miocene.

Catapsydrax parvulus Bolli, Loeblich, and Tappan, new species

Plate 7, Figures 10a–c

Test free, tiny, subglobular, low trochospiral, periphery broadly rounded; chambers ovate, increasing rapidly in size as added, four to five per whorl, mostly with four in the final whorl; sutures distinct, slightly depressed, oblique, somewhat curved on the spiral side; wall calcareous, finely perforate, surface smooth; primary aperture interiomarginal, umbilical and covered over by an arched blisterlike bulla, with a single very low arched or slitlike infralaminal accessory aperture opening at one side.

Greatest diameter of holotype 0.16 mm., thickness 0.13 mm. Paratypes range from 0.13 to 0.18 mm. in diameter.

Remarks: This species differs from *Catapsydrax dissimilis* (Cushman and Bermudez) in its much smaller size, being about one-fourth the diameter; in the less globular and less inflated chambers and more even periphery; and in having only a single infralaminal accessory aperture rather than two to four.

Types and occurrence: Holotype (USNM P4219) and unfigured paratypes (USNM P4822) from the Miocene Lengua formation (*Globorotalia mayeri* zone), in a ditch on the north side of Cunjal Road, southern Trinidad, B. W. I.

Catapsydrax stainforthi Bolli, Loeblich, and Tappan, new species

Plate 7, Figures 11a–c

Test free, small, trochospiral, chambers subglobular to ovate, forming about two whorls, with four or rarely five chambers in the final whorl; sutures distinct, radial, straight to curved, depressed; wall calcareous, perforate, surface pitted; primary aperture interiomarginal, umbilical, and covered by a single umbilical bulla with a small infralaminal accessory aperture opening over each suture of the final whorl.

Greatest diameter of holotype 0.36 mm., thickness 0.26 mm. Paratypes range from 0.26 to 0.42 mm. in diameter.

Remarks: *Catapsydrax stainforthi*, new species, differs from *C. dissimilis* (Cushman and Bermudez) in being about one-half as large, and in having a more closely appressed bulla which may extend a short way along the sutures and which has much smaller arched accessory openings that are restricted to the area over the sutures, instead of the relatively large arches of *C. dissimilis* which may open over much of the umbilical area of a chamber. It differs from *C. parvulus*, new species, and *C. unicavus*, new species, in having the four or more smaller accessory openings beneath the umbilical bulla, rather than a single larger opening at one side only.

The specific name is given in honor of R. M. Stainforth, in recognition of his work on the planktonic Foraminifera.

Types and occurrence: Holotype (USNM P4840) and unfigured paratype (USNM P4841) from the Cipero formation, *Catapsydrax stainforthi* zone (Miocene), Cipero Coast section, Trinidad, B. W. I.

Unfigured paratypes (USNM P4842) from the Ste. Croix member of the Brasso formation (basal *Globigerinatella insueta* zone, Miocene), Ste. Croix quarry, near Broomage trigonometric station, south of Princes Town, Naparima region, Trinidad, B. W. I.

Catapsydrax unicavus Bolli, Loeblich, and Tappan, new species

[Plate 7, Figures 9a–c

Test free, small, trochospiral, low-spired, periphery rounded; chambers subglobular, arranged in two whorls, only a few chambers per whorl, ranging from six in the first whorl to only four in the final whorl; sutures distinct, depressed, slightly curved; wall calcareous, perforate, surface punctate or cancellate in appearance, primary aperture interiomarginal, umbilical, and covered by a small subquadrate bulla which is attached at three sides, with an arched infralaminal accessory opening at the fourth side.

Greatest diameter of holotype 0.31 mm., thickness 0.21 mm. Paratypes range from 0.26 to 0.36 mm. in greatest diameter.

Remarks: *Catapsydrax unicavus*, new species, differs from *C. dissimilis* (Cushman and Bermudez) in being somewhat smaller, with less inflated chambers and less depressed sutures, and the umbilical bulla has a single accessory opening rather than two to four as in *C. dissimilis*. *Catapsydrax parvulus*, new species, also has a single accessory opening, but differs in being much smaller, with a nearly smooth surface, less globular chambers and nearly flush sutures.

Types and occurrence: Holotype (USNM P4216) and unfigured paratype (USNM P4217) from the Cipero formation, *Globigerina ciperoensis* zone, exposure on San Fernando By-pass road, Trinidad, B. W. I. Collected by H. M. Bolli.

Unfigured paratypes (USNM P4837) from the Cipero formation, *Globigerinatella insueta* zone (Miocene) Cipero Coast section, Trinidad, B. W. I. Collected by Hans G. Kugler.

Genus Globigerinita Bronnimann, 1951

Plate 8, Figures 1a–2c

Globigerinita Bronnimann, Contr. Cushman Found. Foram. Res., vol. 2, pt. 1, p. 18, 1951.

Type species: *Globigerinita naparimaensis* Bronnimann, 1951. Fixed by original designation and monotypy.

Test free, trochospiral; chambers spherical to ovate; sutures depressed, radial; wall calcareous, perforate, radial in structure, surface smooth, pitted or hispid; primary aperture interiomarginal, umbilical, in the final stage this aperture is completely covered by an irregular bulla covering the umbilicus and expanding along the earlier sutures, with numerous infralaminal accessory apertures along the margins, both at the junction with the sutures of earlier chambers and along the contact with the primary chambers.

Remarks: *Globigerinita* differs from *Globigerina* d'Orbigny in the presence of the umbilical bulla with multiple infralaminal accessory apertures. It differs from *Globigerinoita* Bronnimann in having a single globigerine primary aperture and a single umbilical-sutural bulla.

Catapsydrax, new genus, differs in having a more restricted bulla, covering only the umbilical region, and in the accessory apertures being only sutural in position, rather than along the entire bulla margin.

The specimen selected as holotype of the type species, *Globigerinita naparimaensis*, is a rather atypical specimen. The transparent "supplementary chamber" of this specimen is not typical in that it is more globular, resembling a normal chamber which has expanded somewhat on the umbilical side. It has only two small accessory apertures instead of the typical numerous openings along the margins of the bulla. However, although it does not show the generic characters well, this specimen is apparently conspecific with Bronnimann's paratypes.

Originally described from the Miocene of Trinidad, the genus has recently been recorded by Conato (1954) from the Italian Pliocene. It has also been recorded in Recent sediments.

Types and occurrence: Holotype of *Globigerinita naparimaensis* (Cushman Coll. 64182), paratypes

(Cushman Coll. 64183, 64184, 64186, and 64187) from the Lengua formation, *Globorotalia menardii* zone, Naparima area; paratypes (Cushman Coll. 64185) from the Lengua formation, *Globorotalia mayeri* zone, Naparima area; and paratypes (Cushman Coll. 64188) from the Lengua formation, *Globorotalia* zone, Cats Hill area. All the above from Trinidad, B. W. I. Figured hypotype (USNM P3914) and unfigured hypotypes (USNM P3915) from the Recent, *Challenger* Station 8, lat. 28°03′15″ N., long. 17°27′ W., at a depth of 620 fathoms.

Range: Miocene to Recent.

Genus Globigerinoita Bronnimann, 1952

Plate 8, Figures 3a–d

Globigerinoita Bronnimann, Contr. Cushman Found. Foram. Res., vol. 3, pt. 1 p. 26, 1952.

Type species: *Globigerinoita morugaensis* Bronnimann, 1952. Fixed by original designation and monotypy.

Test free, trochospiral; chambers spherical to ovate; sutures depressed, radial to curved; wall calcareous, perforate, radial in structure, surface spinose; primary aperture umbilical in position, with one or more secondary sutural apertures as in *Globigerinoides* on the spiral side, in the adult stage the primary aperture is covered by an umbilical bulla and the secondary apertures of the spiral side may also be covered by sutural bullae, with commonly two to three accessory infralaminal apertures at the margins of each of the bullae.

Remarks: *Globigerinoita* differs from *Globigerinita* Bronnimann in having the secondary spiral *Globigerinoides* apertures and in having two or more bullae, one over the primary umbilical aperture and others covering the secondary sutural apertures of the spiral side. *Globigerinoita* differs from *Globigerinatheka* Bronnimann in having a *Globigerinoides* stage, followed by the development of one or more bullae covering the primary and secondary apertures. In *Globigerinatheka* the primary aperture is covered by an enveloping final chamber as in *Orbulina*, and the bullae cover only the secondary apertures.

Types and occurrence: Holotype (USNM P3913) and figured and unfigured paratypes (USNM P3212) from the Miocene Lengua formation, *Globorotalia menardii* zone, Moruga area, Trinidad, B. W. I.

Range: Miocene.

Genus Globigerinatheka Bronnimann, 1952

Plate 7, Figures 12a–c

Globigerinatheka Bronnimann, Contr. Cushman Found. Foram. Res., vol. 3, pt. 1, p. 27, 1952.

Type species: *Globigerinatheka barri* Bronnimann, 1952. Fixed by original designation and monotypy.

Test free, globular, early chambers trochospiral as in *Globigerina*, later with a large enveloping final chamber covering the previous umbilical side as in *Orbulina;* sutures depressed, radial; wall calcareous, perforate, radial in structure; primary aperture of the early *Globigerina* stage interiomarginal, umbilical, but this is covered in the adult by the final enveloping chamber, the secondary sutural apertures multiple on the spiral side and covered by small bullae, each of which have one or more small arched infralaminal accessory apertures.

Remarks: *Globigerinatheka* has a stage like *Globigerapsis*, new genus, preceding the development of bullae, whereas *Globigerinita* Bronnimann has a *Globigerina* stage followed by the development of a very irregular umbilical-sutural bulla.

Globigerinoita Bronnimann has an early *Globigerinoides* stage with one or more sutural secondary apertures on the spiral side, with bullae covering both the primary and secondary apertures.

Types and occurrence: Holotype of *Globigerinatheka barri* Bronnimann (USNM P3919) and paratypes (USNM P3213) from the Eocene Mount Moriah formation, Harmony Hall Well 2, core 10, 11, 1,176–88 feet, 1,198–1,212 feet, Trinidad, B. W. I. Figured hypotype (USNM P3922) from the Eocene Navet formation (Penitence Hill marl), block in the Oligocene Nariva formation, Pointe-a-Pierre, Trinidad, B. W. I.

Range: Middle to upper Eocene.

Genus Globigerinatella Cushman and Stainforth, 1945

Plate 8, Figures 4–7c

Globigerinatella Cushman and Stainforth, Cushman Lab. Foram. Res., Spec. Publ. 14, p. 68, 1945.

Type species: *Globigerinatella insueta* Cushman and Stainforth, 1945. Fixed by original designation and monotypy.

Test free, subglobular, early portion trochospiral with the final chamber usually embracing; wall calcareous, perforate, radial in structure, surface smooth or pitted; aperture in the early stage interiomarginal, umbilical, in the later chambers with secondary sutural and areal apertures, surrounded by distinct lips, with small knobby pustulelike bullae covering the areal secondary apertures, or more irregular spreading sutural bullae covering the secondary sutural apertures, all bullae may have infralaminal accessory apertures.

Remarks: Bronnimann (1950b, p. 80) discussed and illustrated in considerable detail the ontogenetic development of *Globigerinatella*, leaving little to be added, other than a mention of the wall structure. He did include, with question, one "aberrant" form which he later referred to the genus *Globigerinita* (1951b, p. 16). The latter genus does not have a stage with multiple areal apertures, and does not have an enveloping final chamber.

Hofker (1954, p. 151) stated of *Globigerinatella:* "Walls in polarized light granular, not radiate as in *Globigerina*." He also stated that specimens from Ecuador showed "reduced toothplates very similar to those found in *Candeina nitida* d'Orbigny."

The wall structure was rechecked for this study and found to be distinctly radial, as in *Globigerina*. Furthermore, *Candeina* also has a radial wall structure. No suggestion of "toothplates" was seen in either genus, unless Hofker referred to the typical lip as a toothplate.

Hofker considered *Globigerinatella* to be related to "*Quadrimorphina*, *Pullenoides*, *Candeina* and possibly also with *Chilostomellina*." As has been shown earlier (Loeblich and Tappan, 1953, p. 93), *Chilostomellina* has a granular wall structure, and a planispiral plan of coiling, and thus is quite distinct from these trochospiral forms with radially built walls.

Globigerinatella is considered to belong unquestionably to the Orbulinidae. It is related to *Globigerina*, as shown by the early trochospiral stages with a single umbilical aperture, and to *Orbulina* in having the strongly embracing final chamber with areal and sutural secondary apertures. It differs from *Globigerina* in the presence of the bullae and accessory apertures, and from *Orbulina* in having the early stage also with areal apertures.

TYPES AND OCCURRENCE: Holotype of *Globigerinatella insueta* Cushman and Stainforth (Cushman Coll. 44040), paratypes here figured (Cushman Coll. 44043a, b) and unfigured (Cushman Coll. 44041, 44042, and 44043); figured topotypes (USNM P3932a, b) and unfigured topotypes (USNM P3931 and P3936) from the Cipero formation, *Globigerinatella insueta* zone (Miocene), Cipero Coast section, Trinidad, B. W. I. Topotypes collected by H. M. Bolli.

RANGE: Miocene.

Family Globorotaliidae Cushman, 1927

TYPE GENUS: *Globorotalia* Cushman, 1927.

Coiling of test trochospiral; chambers angular to ovate or spherical; wall calcareous, perforate, radial in structure; primary aperture extraumbilical-umbilical, may have secondary sutural apertures on spiral or umbilical side.

RANGE: Cretaceous to Recent.

Genus Praeglobotruncana Bermudez, 1952

PLATE 9, FIGURES 1a–4c

Praeglobotruncana BERMUDEZ, Venezuela Minist. Minas, Bol. Geol., vol. 2, No. 4, p. 52, 1952.

Rotundina SUBBOTINA, Trudy Vses. Neft. Naukno-Issledov. Geol.-Razved. Inst., n. ser. 76, p. 165, 1953. (Type species: *Globotruncana stephani* Gandolfi, 1942. Fixed by original designation.)

?*Hedbergina* BRONNIMANN and BROWN, Eclog. Geol. Helvetiae, vol. 48 (1955), No. 2, p. 529, 1956. (Type species: *Globigerina seminolensis* Harlton, 1927. Fixed by original designation and monotypy.)

TYPE SPECIES: *Globorotalia delrioensis* Plummer, 1931. Fixed by original designation.

Test free, trochospiral, biconvex to spiroconvex, umbilicate, periphery rounded to subangular, or with a moderate keel in the early stages, commonly progressively less prominent in the later development; chambers globular, ovate or subangular; sutures on the spiral side depressed to elevated and thickened or even beaded, radial or curved, on the umbilical side depressed and radial; wall calcareous, finely perforate, radial in structure, surface smooth to hispid; aperture interiomarginal, a relatively high and open extraumbilical-umbilical arch bordered above by a narrow lip or spatulate flap commonly directed toward the umbilicus, and in forms with a broad open umbilicus successive apertural flaps may remain visible to present a serrate or scalloped border around the umbilicus.

REMARKS: Although the type species of *Praeglobotruncana* had been originally described as belonging to *Globorotalia*, Bermudez did not give any comparisons of his proposed new genus to *Globorotalia*, but considered it ancestral to *Globotruncana*, because of its having a more open umbilicus. Bermudez did not describe the apertural characters completely, stating only that the aperture was a simple groove in the base of the septal face of the final chamber (i. e., interiomarginal). In the type species selected, the aperture, like that of a typical *Globorotalia*, consists of an extraumbilical-umbilical arch bordered by a lip. It is perhaps somewhat more open and directed more in an umbilical direction.

Rotundina Subbotina, 1953, (with *Globotruncana stephani* Gandolfi as type species) was said by the describer to be characterized by an open umbilicus and aperture situated near the umbilical ends of the chambers, extending for some distance along the peripheral suture. Near the umbilicus an outgrowth of the wall was said to be present that, taken together, produced a wide rim or border surrounding the umbilicus. Reichel (1949) had provisionally placed *Globotruncana stephani* Gandolfi in *Globotruncana*, s. s., although stating that it could equally well be placed in *Globorotalia*. He figured a specimen that shows an umbilicus bordered by such a scalloped lamellar expansion. On topotypes obtained from Reichel, this feature is not evident and sutures are radial into the open umbilicus. However, a suite of specimens of *Praeglobotruncana delrioensis* (Plummer) included a few possessing large and well-developed apertural lips. These projected somewhat above the normal curvature of the chamber, so that the final lip, together with the earlier ones, presented an irregular umbilical margin. This represents the feature mentioned by Subbotina and Reichel and may also be observed in occasional specimens of many of the other species of *Praeglobotruncana*. A specimen of *P. planispira* (Tappan) is here figured which excellently demonstrates this feature. Thus, *Rotundina stephani* and *Praeglobotruncana delrioensis* possess identical apertural characteristics, and as they are congeneric, *Rotundina* Subbotina is suppressed as a junior synonym.

Bermudez also included *Globotruncana appenninica* Renz in *Praeglobotruncana*, but this species is a true *Rotalipora* as has been noted by Reichel (1949, p. 604), Sigal (1952b, p. 24), Hagn and Zeil (1954, p. 22) and Küpper (1955, p. 114). A specimen figured here also shows the well developed secondary sutural apertures typical of *Rotalipora*.

Hedbergina was described by Bronnimann and Brown as a globigerine form in the family Globotruncanidae, with a small umbilicus and apertural flaps but no cover plate and no peripheral keel. It was considered to be ancestral to *Ticinella* [= *Rotalipora*], although lacking secondary apertures. The type species, *Globigerina seminolensis* Harlton, is a Cretaceous species, represented only by the holotype, which was found as contamination or a possible outlier in the Pennsylvanian from the Ardmore basin of Oklahoma. As the type lacks the most important character of the Globotruncanidae (the tegilla) it cannot be placed in this family, and the absence of secondary apertures shows that it is not a *Ticinella.* This type species was an unfortunate selection, as the central portion of the holotype is completely obscured by matrix. As its true stratigraphic position is unknown it cannot be conclusively checked on other material. This poorly preserved specimen (here refigured) could easily be fit into a number of the various species of "*Globigerina*," *Praeglobotruncana*, etc., described from the Lower and Upper Cretaceous within a relatively short distance from the Pennsylvanian outcrop. Bronnimann and Brown state that the type species, *G. seminolensis*, is "rather rough-walled, coarsely granular", with "markedly elongated" chambers, and an interiomarginal aperture, bordered by a short apertural flap, opening into the umbilicus. The holotype of the species is smooth-walled, and has a finely perforate test, and the aperture and umbilicus are both completely obscured by extraneous material. Bronnimann and Brown figured a specimen from Cuba, which they referred to *G. seminolensis*, but they did not give any exact stratigraphic data for the Cuban specimen either. The figures of this form also show a filled umbilicus, with no indication of the umbilical and apertural characters they mentioned. Furthermore, the chambers of both specimens that have been figured are nearly spherical, and show no indication of the elongation mentioned by Bronnimann and Brown. The only character they indicated which could separate this species from *Praeglobotruncana*, is the absence of a keel, and this is not considered here to be of generic significance. There are many gradations from rounded to slightly compressed to keeled species in most coiled genera of calcareous Foraminifera. Hence, *Hedbergina* is tentatively considered to be a synonym of *Praeglobotruncana*, although, because the position of the aperture cannot be definitely determined on the basis of the material available, it might possibly be a species of *Globigerina.*

Praeglobotruncana is regarded as one of the more primitive planktonic genera, and possibly gave rise not only to other genera of the Globorotaliidae but also to the Globotruncanidae and Orbulinidae, and possibly even to the Hantkeninidae. Various early species show tendencies in these various directions. Perhaps the closest relationship is to *Globorotalia*, which differs in having a more extraumbilical aperture, in being more prominently keeled, and in having ovate to angular chambers. *Praeglobotruncana* has a resemblance to *Globigerina* d'Orbigny in having spherical or ovate chambers and a more umbilically directed aperture, but differs in the somewhat extraumbilical extension of the aperture and the faint keel which may be developed in the early stages of some species. The broad apertural lips are also not characteristic of *Globigerina.* Both of these genera could thus have arisen from *Praeglobotruncana* by slight modifications in apertural position and chamber shape.

Fusion of the apertural lips at their umbilical margins could leave sutural openings and give rise to the *Rotalipora* group. A continued increase in the development of the apertural flaps until they completely covered the umbilicus and attached at their opposite margin, coupled with a gradual restriction in the position of the aperture from extraumbilical-umbilical to only umbilical, would give rise to *Rugoglobigerina* and *Globotruncana.*

Other species, such as *P. subcretacea* (Tappan) [=*Hastigerinella subcretacea* Tappan], show a tendency to develop radially elongate chambers, and may show a relationship to the Hantkeninidae. *Schackoina* does show a trochospiral coiling, differing only in the restriction of the aperture to a completely extraumbilical position and in the development of tubulospines.

Praeglobotruncana is restricted to the Cretaceous, these globular chambered forms not being found in the same strata as true *Globorotalia.* Many Cretaceous species originally placed in various other planktonic genera also belong to *Praeglobotruncana* (i. e., some "*Globigerina*," "*Hastigerinella*," "*Globorotalia*," "*Globotruncana*," etc.), as they possess these apertural and test characters in common, but do not have the specialized features of the genera to which they had previously been referred.

Types and occurrence: Holotype of *Globorotalia delrioensis* Plummer (type species of *Praeglobotruncana*) in the Paleontological Research Institute, Ithaca, New York, from the Cenomanian, Del Rio clay, on right bank of Shoal Creek in a steep slope just south of the Thirty-fourth Street bridge in Austin, Travis County, Texas. Figured topotype (USNM P4481) from the same locality, collected by H. T. and A. R. Loeblich, Jr., July 1940.

Figured topotype of *Globotruncana stephani* Gandolfi (USNM P4848), the type species of *Rotundina* Subbotina, and unfigured topotype (USNM P4832) from the Cenomanian, Breggia number 56, Canton Ticino, Switzerland. Received from Professor M. Reichel.

Figured hypotype of *Praeglobotruncana planispira* (Tappan) (USNM P4875), from the Albian Gault clay, brick pit of the London Brick Co., Arlesey, England. Collected by H. T. and A. R. Loeblich, Jr., 1953.

Figured holotype of *Globigerina seminolensis* Harlton (USNM 71380), a Cretaceous specimen erroneously reported to be from the Pennsylvanian (upper Glenn formation) from the SW¼, SE¼, NW¼ sec. 20, T. 5S., R. 1E., Carter County, Oklahoma.

Range: Aptian to Maestrichtian.

Genus Rotalipora Brotzen, 1942 [2]

Plate 9, Figures 5a–7c and Plate 10, Figures 1a–c

Rotalipora Brotzen, Sveriges Geol. Undersökning, Avh. ser. C, No. 451 (Årsbok. 36, No. 8), p. 32, 1942.

Thalmanninella Sigal, Rev. de l'Inst. Français du Pétrole et Annales des Combustibles liquides, vol. 3, No. 4, p. 101, 1948. (Type species: *Thalmanninella brotzeni* Sigal, 1948. Fixed by original designation and monotypy.)

Ticinella Reichel, Eclog. Geol. Helvetiae, vol. 42, No. 2, p. 600, 1950. (Type species: *Anomalina roberti* Gandolfi, 1942. Fixed by original designation and monotypy.)

Type species: *Rotalipora turonica* Brotzen, 1942. Fixed by original designation and monotypy.

Test free, trochospiral, biconvex to planoconvex, umbilicate, periphery rounded or with a single keel; chambers ovate to angular-rhomboid; sutures on spiral side curved, depressed to elevated, may be beaded, on umbilical side flush to depressed, radial or slightly curved; wall calcareous, perforate, radial in structure, surface in general smooth; primary aperture interiomarginal, extraumbilical-umbilical, and may be bordered above by a lip, secondary apertures sutural on the umbilical side, one per suture or rarely two or more, and each may be bordered by a narrow lip.

Remarks: *Rotalipora* differs from *Globotruncana* Cushman in possessing an interiomarginal, extraumbilical-umbilical primary aperture, in having secondary sutural apertures and an open umbilicus, and in lacking the umbilical tegilla.

Thalmanninella Sigal is here considered a synonym of *Rotalipora*, as an examination of specimens identified by the authors of both type species shows no fundamental differences. The secondary sutural apertures may be situated in various positions along the sutures, from the midregion of the suture to the inner margin of the umbilical rim, and may then be aligned at an angle. In every case these sutural apertures open into the chambers themselves and not into the umbilicus. The topotype of *Thalmanninella brotzeni* Sigal, here figured, shows some of these secondary apertures which are as definitely sutural in position as those of the figured specimen of *Rotalipora turonica* Brotzen. The remaining differences are only of specific importance.

Ticinella was defined by Reichel as having apertural characters identical with those of *Thalmanninella* Sigal. He separated *Ticinella* on the basis of the globular chambers and absence of a keel other than a slight indication of one in the early chambers. *Thalmanninella* was characterized by a simple marginal keel, but this was also stated to be commonly absent in the last chambers. Both have been recorded from the Cenomanian, although *Ticinella* has been recorded as lower in the Cenomanian and ?Albian. Nevertheless, as their sole distinction is a matter of degree (*Ticinella* is without a keel except in the early chambers and *Thalmanninella* may be without one in the later chambers), we consider *Ticinella* Reichel also a junior synonym of both *Thalmanninella* Sigal and *Rotalipora* Brotzen.

Types and occurrence: Figured hypotype of *Rotalipora turonica* Brotzen (USNM P50) and unfigured hypotypes (USNM P4237) from the lower Turonian, Gristow, Sweden.

Figured topotype of *Thalmanninella brotzeni* Sigal (USNM P3930) from the middle Cenomanian, Sidi-Aïssa, Algeria.

Figured hypotype of *Ticinella roberti* (Gandolfi) (USNM P4829) from Breggia Number 27, lower Cenomanian, Canton Ticino, Switzerland.

Figured specimen of *Rotalipora* cf. *appenninica* (Renz) (USNM P4873) from the Cenomanian Del Rio formation on right bank of Shoal Creek just south of the 34th Street bridge, in Austin, Travis County, Texas. Collected by H. T. and A. R. Loeblich, Jr.

Range: Albian to Turonian.

Genus Globorotalia Cushman, 1927

Plate 10, Figures 2a–4c

Globorotalia Cushman, Contr. Cushman Lab. Foram. Res., vol. 3, pt. 1, p. 91, 1927.

Truncorotalia Cushman and Bermudez, Contr. Cushman Lab. Foram. Res., vol. 25, p. 35, 1949. (Type species: *Rotalina truncatulinoides* d'Orbigny, 1839. Fixed by original designation.)

Turborotalia Cushman and Bermudez, Contr. Cushman Lab. Foram. Res., vol. 25, p. 42, 1949. (Type species: *Globorotalia centralis* Cushman and Bermudez, 1937. Fixed by original designation.)

Acarinina Subbotina, Trudy Vses. Neft. Naukno-Issledov. Geol.-Razved. Inst., n. ser. 76, p. 219, 1953. (Type species: *Acarinina acarinata* Subbotina, 1953. Fixed by original designation.)

Globanomalina Haque, Palaeontol. Pakistanica, vol. 1, p. 148, 1956. (Type species: *Globanomalina ovalis* Haque, 1956. Fixed by original designation.)

?*Pseudogloborotalia* Haque, Ibid., vol. 1, p. 184, 1956. (Type species: *Pseudogloborotalia ranikotensis* Haque, 1956. Fixed by original designation.)

Type species: *Pulvinulina menardii* (d'Orbigny) var. *tumida* Brady, 1877. Fixed by original designation and monotypy.

Test free, trochospiral, biconvex to umbilicoconvex, umbilicate, periphery with or without a single keel; chambers ovate to angular rhomboid or angular conical; sutures on the spiral side depressed to elevated, curved or radial, may be thickened on the umbilical side, depressed and radial; wall calcareous, finely perforate, radial in structure, surface smooth to hispid; aperture interiomarginal, an extraumbilical-umbilical arch bordered by a lip, varying from a narrow rim to a broad spatulate to triangular flap.

Remarks: *Globorotalia* differs from *Globotruncana* Cushman in having an interiomarginal, extraumbilical-umbilical aperture and a simple umbilicus, and in lacking the umbilical tegilla and accessory intralaminal

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[2] The genus *Biticinella* Sigal was recently described from the Vraconnian as related to *Rotalipora*, in having accessory apertures at the posterior border of each chamber. As the present article was already in press and no specimens of *Biticinella* were available to the writers, the genus is not fully discussed herein. If there are true accessory apertures at the posterior border of the chambers and the test is asymmetrically coiled as described it would seem to be related to the Globorotaliidae, although no other genus of this family has accessory apertures on both sides. If however, the test is planispiral, the aperture equatorial as shown, and the "accessory apertures" should prove to be relict apertures instead, *Biticinella* would become a synonym of *Planomalina*. An examination of additional specimens is necessary to correctly place the genus.

and infralaminal apertures. It differs from *Truncorotaloides* Bronnimann and Bermudez in lacking the secondary sutural apertures on the spiral side.

Other generic names have been proposed for various species of *Globorotalia*, largely based on chamber shape. However, in considering all species there are gradations from each extreme of chamber shape or size of umbilicus to the typical form of *Globorotalia*. Thus although certain extreme forms may appear to represent distinctive types, the other species are intermediate in character, so that no sharp boundaries appear.

Truncorotalia Cushman and Bermudez included species with an umbilico-convex form, sharply angular-rhomboid chambers and an elongate and slitlike aperture. However, these features are regarded as only of specific importance, and intermediate species between this form and that represented by *Globorotalia tumida* are impossible to separate.

Turborotalia Cushman and Bermudez included species with a globose form, with a small or indistinct umbilicus, and with a narrower apertural lip. There are also many intermediate forms, and the distinctions are again regarded only as of specific value.

Acarinina Subbotina was proposed for the same group of species as *Turborotalia*, and even included its type species. Hence it also becomes a junior synonym.

Haque (1956, p. 147) described *Globanomalina*, separating it from *Globigerina* d'Orbigny, because of the very smooth test as compared to the spinose test of *Globigerina bulloides* d'Orbigny, and because of the peripheral rather than umbilical aperture. However, the majority of the described species of *Globigerina*, including *G. bulloides*, may also have a smooth surface, and the trochospiral test and the extraumbilical-umbilical position of the aperture of *Globanomalina* prove it to be a synonym of *Globorotalia*. The type species, *Globanomalina ovalis*, is apparently close to the early Paleocene group of *Globorotalia* with rounded, keelless chambers, e. g., *Globorotalia compressa* (Plummer) and *Globorotalia pseudobulloides* (Plummer).

Haque (1956, p. 185) also described *Pseudogloborotalia*, separating it from *Globorotalia* mainly on the basis of the smooth and shiny test, whereas he stated that Cushman characterized *Globorotalia* as having a thick cancellated surface. Cushman (1927, p. 91) stated that *Globorotalia* has a "wall frequently roughened throughout," but did not state it to be cancellated, and the type species, *G. tumida*, has a smooth surface. Thus this basis for separation is invalid. *Pseudogloborotalia* is here questionably placed as a synonym of *Globorotalia*, and is also questionably considered a planktonic species. Specimens deposited in the U. S. National Museum by Haque closely resemble the genus *Globorotalites* Brotzen, which is not a planktonic form, but a study of additional and better preserved material will be necessary to definitely place *Pseudogloborotalia*.

Types and occurrence: Syntypes of *Pulvinulina menardii tumida* Brady (USNM P3143), the type species of *Globorotalia* Cushman, from the Post Tertiary of New Ireland.

Figured topotype (USNM P4542) of *Rotalina truncatulinoides* d'Orbigny (the type species of *Truncorotalia*) and unfigured topotypes (USNM P4231) from d'Orbigny's original sample, Recent, Ile de Teneriffe, Canaries.

Holotype of *Globorotalia centralis* Cushman and Bermudez (Cushman Coll. 23426) the type species of *Turborotalia*, and paratypes (Cushman Coll. 23425) from the Eocene, under railroad bridge on Central Highway, located in Jicotea, Santa Clara Province, Cuba. Collected by P. J. Bermudez.

Hypotypes of *Pseudogloborotalia ranikotensis* Haque (USNM P5398) from the Paleocene (Ranikot formation), Nammal Gorge, Salt Range, Pakistan. Sent by A. F. M. Mohsenul Haque.

Hypotypes of *Globanomalina ovalis* Haque (USNM P5399) from the lower Eocene, upper part of the lower Laki formation, Nammal Gorge, Salt Range, Pakistan. Sent by A. F. M. Mohsenul Haque.

Range: Paleocene to Recent.

Genus Truncorotaloides Bronnimann and Bermudez, 1953

Plate 10, Figures 5a–c

Truncorotaloides Bronnimann and Bermudez, Journ. Paleontol., vol. 27, No. 6, p. 817, 1953.

Type species: *Truncorotaloides rohri* Bronnimann and Bermudez, 1953. Fixed by original designation.

Test free, trochospiral, biconvex to umbilicoconvex, umbilicate, with or without a single keel; chambers ovate to angular-rhomboid; sutures depressed, radial to oblique on the spiral side, radial and depressed on the umbilical side; wall calcareous, perforate, radial in structure, surface prominently hispid throughout; primary aperture interiomarginal, extraumbilical-umbilical, with single secondary sutural apertures on the spiral side at the inner margin of the later chambers where they lie against the previous whorl.

Remarks: *Truncorotaloides* resembles *Globigerinoides* Cushman in having the small secondary apertures on the spiral side, but differs in having the primary aperture interiomarginal, extraumbilical-umbilical, rather than completely umbilical.

Truncorotaloides differs from *Globorotalia* Cushman in the presence of the secondary sutural apertures on the spiral side.

Types and occurrence: Holotype of *Truncorotaloides rohri* Bronnimann and Bermudez (USNM P4233) from the Eocene Navet formation, marl pebble bed, Duff road area, near Kelly junction, about 7 miles east of Pointe-a-Pierre, Central Trinidad, B. W. I.

Range: Eocene.

Family Globotruncanidae Brotzen, 1942

Type genus: *Globotruncana* Cushman, 1927.

Coiling of test trochospiral; chambers spherical to angular, commonly truncate or keeled; wall calcareous, perforate, radial in structure; primary aperture umbilical in position but covered by a spiral system of tegilla, accessory intralaminal and infralaminal apertures present.

RANGE: Upper Cretaceous.

Abathomphalus Bolli, Loeblich, and Tappan, new genus

PLATE 11, FIGURES 1a–c

TYPE SPECIES: *Globotruncana mayaroensis* Bolli, 1951. Derivation: *Abathes*, Gr., shallow + *omphalos*, Gr., umbilicus; gender, masculine.

Test free, trochospiral, biconvex to concavoconvex, almost nonumbilicate, periphery with a single or double keel; sutures depressed, curved and sometimes beaded on the spiral side, depressed and radial on the umbilical side; wall calcareous, perforate, radial in structure, commonly ornamented with fine nodes, and the peripheral keels and sutures may also be beaded; primary aperture interiomarginal, extraumbilical, as a rule covered by a continuous umbilical tegillum of irregular outline, with accessory infralaminal apertures situated at the suture contacts with the tegillum.

REMARKS: *Abathomphalus*, new genus, differs from *Globotruncana* Cushman in lacking a wide and deep umbilicus with a sharply angled rim and delicate tegilla extending from each chamber and in the interiomarginal, extraumbilical position of the primary aperture.

In *Abathomphalus*, new genus, the umbilical area is not open, the final whorl of chambers all meeting ventrally, although their junction may be obscured by the single umbilical tegillum, which appears to be an extension from the final chamber. The accessory apertures are always infralaminal, not both infralaminal and intralaminal as in *Globotruncana*.

Abathomphalus, new genus, differs from *Globorotalia* Cushman in the presence of the tegillum and accessory infralaminal apertures. It differs from *Rotalipora* Brotzen in lacking the secondary sutural apertures on the umbilical side, in having a tegillum and accessory infralaminal apertures.

TYPES AND OCCURRENCE: Holotype (Cushman Coll. 59685) and paratypes (Cushman Coll. 59686) of *Abathomphalus mayaroensis* (Bolli) from the Maestrichtian (*Abathomphalus mayaroensis* zone), Guayaguayare formation, subsurface section in the Guayaguayare area, Trinidad, B. W. I.

Figured hypotype (USNM P4833) and unfigured hypotypes (USNM P4833, P4861, P4862 and P4863) from the Maestrichtian Guayaguayare formation (*Abathomphalus mayaroensis* zone), from a subsurface core, Guayaguayare area, southeastern Trinidad, B. W. I.

RANGE: Maestrichtian.

Genus Rugoglobigerina Bronnimann, 1952

PLATE 11, FIGURES 2a–5c

Rugoglobigerina BRONNIMANN, Bull. Amer. Paleontol., vol. 34, No. 140, p. 16, 1952.

Plummerella BRONNIMANN (not *Plummerella* DeLong, 1942), Bull. Amer. Paleontol., vol. 34, No. 140, p. 37, 1952. (Type species: *Rugoglobigerina* (*Plummerella*) *hantkeninoides hantkeninoides* Bronnimann, 1952. Fixed by original designation.)

Plummerita BRONNIMANN, Contr. Cushman Found. Foram. Res., vol. 3, pts. 3, 4, p. 146, 1952 (new name for *Plummerella* Bronnimann, 1952).

Trinitella BRONNIMANN, Bull. Amer. Paleontol., vol. 34, No. 140, p. 56, 1952. (Type species: *Trinitella scotti* Bronnimann, 1952. Fixed by original designation and monotypy.)

?*Kuglerina* BRONNIMANN and BROWN, Eclog. Geol. Helvetiae, vol. 48 (1955), No. 2, p. 557, 1956. (Type species: *Rugoglobigerina rugosa rotundata* Bronnimann, 1952. Fixed by original designation and monotypy.)

TYPE SPECIES: *Globigerina rugosa* Plummer, 1926. Fixed by original designation.

Test free, trochospiral, biconvex, umbilicate, periphery rounded to slightly angular; chambers spherical, hemispherical, radial elongate or rarely angular in the later portion; sutures radial to slightly curved on the spiral side, radial on the umbilical side, depressed throughout; wall calcareous, perforate, radial in structure, surface typically rugose with numerous large pustles which may coalesce into distinct ridges, radiating from the midpoint of each chamber on the periphery, or much produced peripherally into spinelike extensions, more rarely smooth; primary apertures interiomarginal, umbilical, in well preserved specimens covered by tegilla perforated by the accessory infralaminal and intralaminal apertures; these are the only openings to the exterior. The tegilla, however, as a rule are partially or wholly broken out in preservation.

REMARKS: *Rugoglobigerina* resembles *Globotruncana* Cushman in the apertural characters and the presence of the umbilical tegilla, but differs in the prominent surface ornamentation and less angular chambers. *Rugoglobigerina* may be regarded as the form ancestral to *Globotruncana*, and various species of the latter genus seem to have branched off from the main *Rugoglobigerina*-stem at different geologic times.

Rugoglobigerina differs from *Globigerina* d'Orbigny in having the umbilical tegilla covering the primary aperture, in having the infralaminal and intralaminal accessory apertures, and often in the characteristic rugose and highly ornamented surface.

In her original description of the type species, Plummer (1926, p. 39) compared it with *Globigerina rosetta* [=*Globotruncana*] stating that the umbilical features were precisely the same. No orbulinids show these umbilical tegilla, but they are characteristic of *Globotruncana*.

Bronnimann originally defined *Rugoglobigerina* with three subgenera: *Rugoglobigerina*, s. s., *Plummerella* (later *Plummerita*, new name, as *Plummerella* was a homonym), and *Trinitella*.

Plummerita was separated from *Rugoglobigerina*, s. s., because of its peripheral spinelike chamber extensions and more flattened spire, but specimens figured by Bronnimann as *Rugoglobigerina reicheli reicheli* (1952b, p. 19, text fig. 4a,b) show two definitely radial-elongate chambers, and others placed in *Plummerella hantkeninoides inflata* show chambers as well rounded as those of typical *Rugoglobigerina* (Bronnimann, 1952b, pl. 41, text fig. 19a,b).

Trinitella was considered to have slightly flattened later chambers, tending toward *Globotruncana*, but this is present only on the last one or two chambers. No true keel as in *Globotruncana* is found in this group.

As all three of these subgenera were from the same horizon and all have the same type of surface ornamentation and apertural characters, it seems probable that these gradations are not accidental, and that only a single genus is present, the differences found being only sufficient to warrant specific separation.

Later, Bronnimann and Brown (1956) described the monotypic genus *Kuglerina*, the type species being one originally considered by Bronnimann as a subspecies of the type species of *Rugoglobigerina*, with which it is associated. The original types were deposited in the U. S. National Museum, and show the general chamber shape and ornamentation characteristic of *R. rugosa*. Bronnimann and Brown state that *Kuglerina* differs from *Rugoglobigerina* in being higher spired and in having a smaller and deeper umbilicus, and in completely lacking umbilical cover plates. The height of the spire and size and depth of the umbilicus are characters of only specific or subspecific rank. Although the apertural character is of greater importance, the apertural region of the type specimens is completely obscured by matrix, and the actual presence or absence of tegilla cannot be determined. Because the species has never been recorded from other localities, the characters can only be those visible on the type specimens, and the tegilla are so fragile that they are only preserved in very fine specimens. Therefore, the basis for separation of this genus is extremely doubtful and we consider it a synonym of *Rugoglobigerina*, the questionable assignation being due only to the poor preservation of the type specimens.

Types and occurrence: Holotype of *Rugoglobigerina rugosa* (Plummer) in the Paleontological Research Institute, Ithaca, New York. Unfigured topotypes (USNM P3928, P3921) from the Navarro (Kemp Clay), Maestrichtian, 10 feet below the contact with the Midway (Paleocene), in the bank of Walker Creek, 6 miles N. 15° E. of Cameron, about 1 mile upstream from the intersection of Walker Creek and the Cameron-Clarkson road, Milan County, Texas. Figured hypotype (USNM P3929) from the Navarro (Corsicana marl), branch of Mustang Creek, 1 mile WSW of Noack, 900 feet downstream from the road and 0.2 mile southwest of Christ Evangelical Lutheran Church, Williamson County, Texas. Collected by A. R. Loeblich, Jr., 1955.

Holotype of *Plummerella hantkeninoides hantkeninoides* Bronnimann (=*Plummerita*, new name) (USNM P4847) from the Maestrichtian, Guayaguayare beds, *Abathomphalus mayaroensis* zone, Trinidad, B. W. I.

Holotype (USNM P4856) of *Trinitella scotti* Bronnimann from the Maestrichtian, Guayaguayare beds, *Abathomphalus mayaroensis* zone, Trinidad, B. W. I.

Figured hypotype (USNM P4838) and unfigured hypotypes (USNM P4823) of *Trinitella scotti* Bronnimann from the Maestrichtian, Navarro (Kemp clay), 10 feet below the Midway (Paleocene) contact, in bank of Walker Creek, 6 miles N. 15° E. of Cameron, about 1 mile upstream from intersection of Walker Creek and the Cameron-Clarkson road, Milam County, Texas.

Holotype of *Rugoglobigerina rugosa rotundata* Bronnimann, the type species of *Kuglerina* Bronnimann and Brown (USNM P5401) from the Maestrichtian Guayaguayare beds, *Abathomphalus mayaroensis* zone, Trinidad, B. W. I.

Range: Turonian to Maestrichtian.

Genus Globotruncana Cushman, 1927

Plate 11, Figures 6–11c

Globotruncana Cushman, Contr. Cushman Lab. Foram. Res., vol. 3, p. 91, 1927.

Rosalinella Marie, Mém. Mus. Hist. Nat. Paris, new ser., vol. 12, p. 237, 1941. (Type species: *Rosalina linneiana* d'Orbigny, 1839. Fixed by original designation.)

Bucherina Bronnimann and Brown, Eclog. Geol. Helvetiae, vol. 48 (1955), No. 2, p. 557, 1956. (Type species: *Bucherina sandidgei* Bronnimann and Brown, 1956. Fixed by original designation and monotypy.)

Rugotruncana Bronnimann and Brown, Ibid., p. 546, 1956. (Type species: *Rugotruncana tilevi* Bronnimann and Brown, 1956. Fixed by original designation.)

Marginotruncana Hofker, Neues Jahrb. Geol. Paläontol., Abh., vol. 103, pt. 3, p. 319, 1956. (Type species: *Rosalina marginata* Reuss, 1845. Fixed by original designation.)

Type species: *Pulvinulina arca* Cushman, 1926. Fixed by original designation and monotypy.

Test free, trochospiral, biconvex, spiroconvex or umbilicoconvex, broadly umbilicate, periphery rounded, with a single keel or truncate with a double keel; chambers ovate, hemispherical, angular rhomboid or angular truncate; sutures on the spiral side curved or radial, depressed to elevated, may be limbate and beaded, on the umbilical side sutures curved or radial, depressed or more rarely elevated; wall calcareous, perforate, radial in structure, surface smooth, rugose or beaded; primary apertures interiomarginal, umbilical, in well preserved specimens covered by tegilla, which are perforated by accessory infralaminal and intralaminal apertures, which are then the only openings to the exterior, the tegilla commonly are partially or wholly broken out in the process of fossilization, or may be preserved only as scalloped fragments.

Remarks: D'Orbigny described the first species of *Globotruncana* in 1839 under the name *Rosalina linneiana*. The genus *Rosalina* had been proposed by d'Orbigny in 1826, with *Rosalina globularis* as type species. In later years several species of *Globotruncana* were described as *Rosalina* (e. g., *Rosalina canaliculata*, *R. marginata*, *R. stuarti*), or *Pulvinulina* (e. g., *Pulvinulina tricarinata*, *P. arca*).

Cushman, in 1927, without referring to *Rosalina*, named the genus *Globotruncana* with *Pulvinulina arca* as type species. In 1933 Thalmann stated that *Rosalina* d'Orbigny, 1826, was a junior synonym of *Discorbis* Lamarck, 1804, and thus not related to the group of species under discussion here. *Globotruncana* is therefore the first valid name for the species originally described as *Pulvinulina arca*.

The true apertural characters of this genus were not given in the original description (Cushman, 1927, p. 91) which stated only "aperture on the ventral side." In his textbook (1928, p. 311) Cushman separated *Globorotalia* and *Globotruncana* solely on the basis of the periphery, the former "periphery acute or rounded, with a single keel," the latter "periphery truncate, usually with a double keel." In the generic description of *Globotruncana* he added, "aperture on the ventral side, often in well-preserved specimens with a thin plate-like structure over the umbilical area."

Galloway (1933, p. 332) described *Globotruncana* as having the "aperture a slit at the base of the last chamber opening into the large umbilicus," and placed it in the Orbulinidae, while placing *Globorotalia* (p. 278) in the Rotaliidae, subfamily Rotaliinae. Galloway's key separated *Globotruncana* from *Globigerina* d'Orbigny only by its having limbate sutures.

Glaessner (1948, p. 150) included *Globotruncana* and *Globorotalia* in the Globorotaliidae, and stated of *Globotruncana*, "aperture large, basal, leading from each chamber into the wide umbilicus which is often concealed by a thin perforate plate."

Some of the French workers, evidently on the basis of Cushman and Galloway's earlier descriptions, considered *Globotruncana* to have a single aperture, as that of *Globorotalia*, separating the two only on the peripheral characters. Marie (1941, p. 237) commented on the separation of *Globorotalia* and *Globotruncana* according to the number of keels, and considered this basis for subdivision invalid. His key considered *Globorotalia* as having a single terminal aperture, on the last chamber face. He then described the new genus *Rosalinella*, with apertures, particularly in the chambers of the last whorl, opening into the umbilicus. He placed *Globotruncana* Cushman, 1927, in the synonymy of his new genus, with *Rosalina* of de Lapparent (not d'Orbigny), etc., selecting as type species *Rosalina linneiana* d'Orbigny. As *Globotruncana* is a valid name and antedates *Rosalinella*, the latter becomes a junior synonym. The type species, *Rosalina linneiana* d'Orbigny, was described from Recent sands of Cuba, where it is undoubtedly reworked from the outcropping Cuban Cretaceous strata.

Reichel (1949, p. 600) considered *Globotruncana* to have four subgenera: *Globotruncana*, s. s., *Rotalipora* Brotzen, *Thalmanninella* Sigal and *Ticinella* Reichel. The latter three subgenera of Reichel are here considered unrelated to *Globotruncana*, and are fully discussed under *Rotalipora*.

Sigal (1952, p. 236) stated that *Globotruncana* and *Globorotalia* had been differentiated by the number of keels, but that in reality the position of the aperture was a more certain criterion, and he thus recognized as genera (not subgenera) *Ticinella* Reichel (with barely delineated keel), *Thalmanninella* Sigal (with one keel), both with secondary umbilical apertures; *Rotalipora* Brotzen with one keel and secondary apertures in sutural slits, and *Globotruncana*, s. s., with one or two keels without secondary apertures.

However, in *Globotruncana*, s. s., only the accessory apertures of the tegilla are visible in perfect specimens, the primary apertures being visible only when the tegilla are broken out in preservation or in the preparation of the fossil material for study. These tegilla and accessory apertures are present on fully preserved specimens of every species.

Rugotruncana was separated from *Globotruncana* by Bronnimann and Brown (1956) because of a surface ornamentation of discontinuous ridges. The genera are otherwise identical, and Bronnimann and Brown admitted (p. 546) that "the morphologic differences between the two genera are slight." We do not regard surface ornamentation as a character of generic value, hence *Rugotruncana* is here considered a synonym of *Globotruncana*. In addition to the type species, Bronnimann and Brown listed other ornamented *Globotruncana* which they considered to belong to *Rugotruncana*, among which were *G. intermedia* Bolli and *G. mayaroensis* Bolli. These two species differ from *Globotruncana* in lacking an open umbilicus, in having only a single tegillum which extends from the final chamber, and has only infralaminal accessory apertures, and the primary aperture is extraumbilical-umbilical in position, instead of truly umbilical. These two species we place in the new genus *Abathomphalus*, and *G. mayaroensis* is the type species.

Bucherina was described by Bronnimann and Brown as a monotypic genus from the Maestrichtian of Cuba, which resembles *Globotruncana* and *Rugotruncana* in having a keel and small apertural flaps, but was said to differ in that these flaps do not extend across the umbilicus to form a true cover plate (tegilla). In nearly all species of *Globotruncana* these fragile tegilla are only partially preserved, and only very rare specimens show them as well preserved as in the specimens here figured. Tegilla were not recognized even in the type species of *Globotruncana* until many years after its original description, and they have not been mentioned in the original descriptions of the majority of species. It is probable that better preserved specimens of *Bucherina sandidgei* will also show the complete umbilical tegilla, and we regard *Bucherina* as a synonym of *Globotruncana*.

Hofker (1956, p. 319) proposed the generic name *Marginotruncana*, with *Rosalina marginata* Reuss as type species. He considered *Globotruncana* to have a strongly reduced protoforamen (primary aperture), which is no longer an open slit, and *Marginotruncana* was said to have lost the protoforamen or to have it fused with a deuteroforamen (secondary aperture). The diagrammatic figures in his text-fig. 1 are highly misleading, as there are not two openings in the final chamber of true *Globotruncana*, and there is no extraumbilical opening into the chamber. If such openings exist in specimens studied by Hofker, they are totally unlike those of the type species of the genus, and his specimens undoubtedly are of a form referable to the family Globorotaliidae, probably *Rotalipora*. The minor differences in proportions of these two openings shown in various "genera" in his text-fig. 1 are certainly of not more than specific value.

As shown in the present paper, and recognized by most authorities on the planktonic genera, true *Globotruncana* has an umbilical primary aperture. In well preserved specimens this is always covered by the umbilical tegilla, the only connection to the outside being through the infralaminal accessory apertures, which open beneath the tegilla, not directly into the chambers themselves.

Hofker selected *Rosalina marginata* Reuss as type species for his genus. In the original description of the species (a true *Globotruncana*), Reuss (1845) mentioned the perpendicularly truncate outer margin (typical of double-keeled forms) and broad umbilicus. The original figures are small and somewhat generalized. However, that of Reuss' fig. 68, pl. 13, from the Plänermergel (Turonian) is here designated as lectotype, as it shows the open umbilicus and other characters mentioned in the original description. Better figures are given by Cushman (1936, pl. 62, fig. 1), of a specimen in the Reuss collection at Cambridge, which is from the original locality. Hagn and Zeil (1954, pl. 2, fig. 4) showed very similar specimens from the Turonian of the Bavarian Alps.

In addition to the lectotype, Reuss also figured as *Rosalina marginata* a specimen (pl. 8, fig. 74) from the lower Planer (Cenomanian) which differed from the written description in lacking an open umbilicus. Because of this character and the apparently extraumbilical aperture, this specimen is probably a species of *Praeglobotruncana* or *Rotalipora*. The geologic occurrence supports this assumption, as true *Globotruncana* does not occur in the Cenomanian, whereas both *Praeglobotruncana* and *Rotalipora* do appear there.

Completely disregarding Reuss' original description of the species (only the later publication of Reuss, 1854, was cited by Hofker) as well as the later descriptions and figures of the species, Hofker figured as *Marginotruncana marginata* (Reuss) a single-keeled form with an extraumbilical aperture. Hofker commented with regard to his text-fig. 6 that itsome what resembled *Rotalipora*, and also stated (p. 323) that no typical *M. marginata* occurs in the Cenomanian-Turonian of southern Germany, although it was originally described from Bohemia and has since been recorded from Bavaria by Hagn and Zeil (1954). Hofker stated (p. 324) that Hagn's form was not true *marginata* (he credited the 1954 publication solely to Hagn, although it was under the joint authorship of Hagn and Zeil), yet Hagn and Zeil's specimens of a double-keeled *Globotruncana* more closely resemble the original figures and description of Reuss, and are geographically closer to the type area, than those of Hofker.

From the illustrations given, it is probable that Hofker identified as the species *marginata*, specimens which are actually *Praeglobotruncana*, although his citation of *Rosalina marginata* Reuss as type species, places the genus *Marginotruncana* as a junior synonym of *Globotruncana*.

In addition to the type species, Hofker also included in *Marginotruncana* the following species of typical *Globotruncana: Rosalina stuarti* Lapparent, *Globotruncana globigerinoides* Brotzen, *Marginotruncana paraventricosa* Hofker (which included *G. ventricosa of* Brotzen, not White) and *Marginotruncana pauperata* Hofker (including *G. marginata* of Visser, not Reuss). He also included other totally unrelated species, such as *G. intermedia* Bolli (an *Abathomphalus*), *G. citae* Bolli (a *Praeglobotruncana*), *G. stephani* var. *turbinata* Reichel (a variety of the type species of *Rotundina*, a junior synonym of *Praeglobotruncana*), *G. ticinensis* Gandolfi (a *Rotalipora* previously placed in *Thalmanninella*, junior synonym of *Rotalipora*), and *G. appenninica* Renz (also a *Rotalipora*). He thus included in his *Marginotruncana*, species with the distinctive characters of the genera *Praeglobotruncana* Bermudez, 1952 (and its synonym *Rotundina* Subbotina, 1953), *Rotalipora* Brotzen, 1942 (and its synonym *Thalmanninella* Sigal, 1948), which belong to the family Globorotaliidae, and the genera *Globotruncana* Cushman, 1927 (and its synonym *Rosalinella* Marie, 1941) and *Abathomphalus* Bolli, Loeblich and Tappan, which belong to the family Globotruncanidae. All but the last of these generic names preoccupy that of Hofker, if all were congeneric.

TYPES AND OCCURRENCE: Holotype of *Pulvinulina arca* Cushman (type species of *Globotruncana*) (Cushman Coll. 5078) from the Mendez shale, near Huiches, Hacienda El Limón, San Luis Potosí, Mexico.

Figured hypotypes of *Globotruncana arca* Cushman (USNM P4242 a-e) from Navarro (Corsicana marl), branch of Mustang Creek, 1.0 miles WSW of Noack, 900 feet downstream (south) from road and 0.2 mile southwest of Christ Evangelical Lutheran Church, Williamson County, Texas. Collected by Noel Brown.

RANGE: Turonian to Maestrichtian.

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